



**WinSRFR 1.0 User Manual  
DRAFT**

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# WinSRFR 1.0 Help & Manual - DRAFT

Surface Irrigation Analysis, Design & Simulation

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*by ALARC*

*WinSRFR is produced by:*

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Agricultural Research Service*

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# 1 Welcome to WinSRFR

WinSRFR is an integrated hydraulic analyses application for surface irrigation systems that combines a simulation engine with tools for irrigation system evaluation, design, and operational analysis. Intended users are irrigation specialists, university extension agents and researchers, consultants, and farmers with moderate to advanced knowledge of surface irrigation hydraulics. WinSRFR is the successor to irrigation modeling software developed over the past 20+ years by the USDA-Agricultural Research Service, namely:

- SRFR:** One dimensional simulation of basin, border, and furrow irrigation
- BASIN:** Level-Basin irrigation design and operations
- BORDER:** Sloping-Border irrigation design and operations

In this initial release, WinSRFR integrates the functionality of those legacy applications. Future releases of WinSRFR will enhance the original analytical capabilities and add new capabilities. Shown here is the [Project Management Window](#), the first window to display when WinSRFR starts.

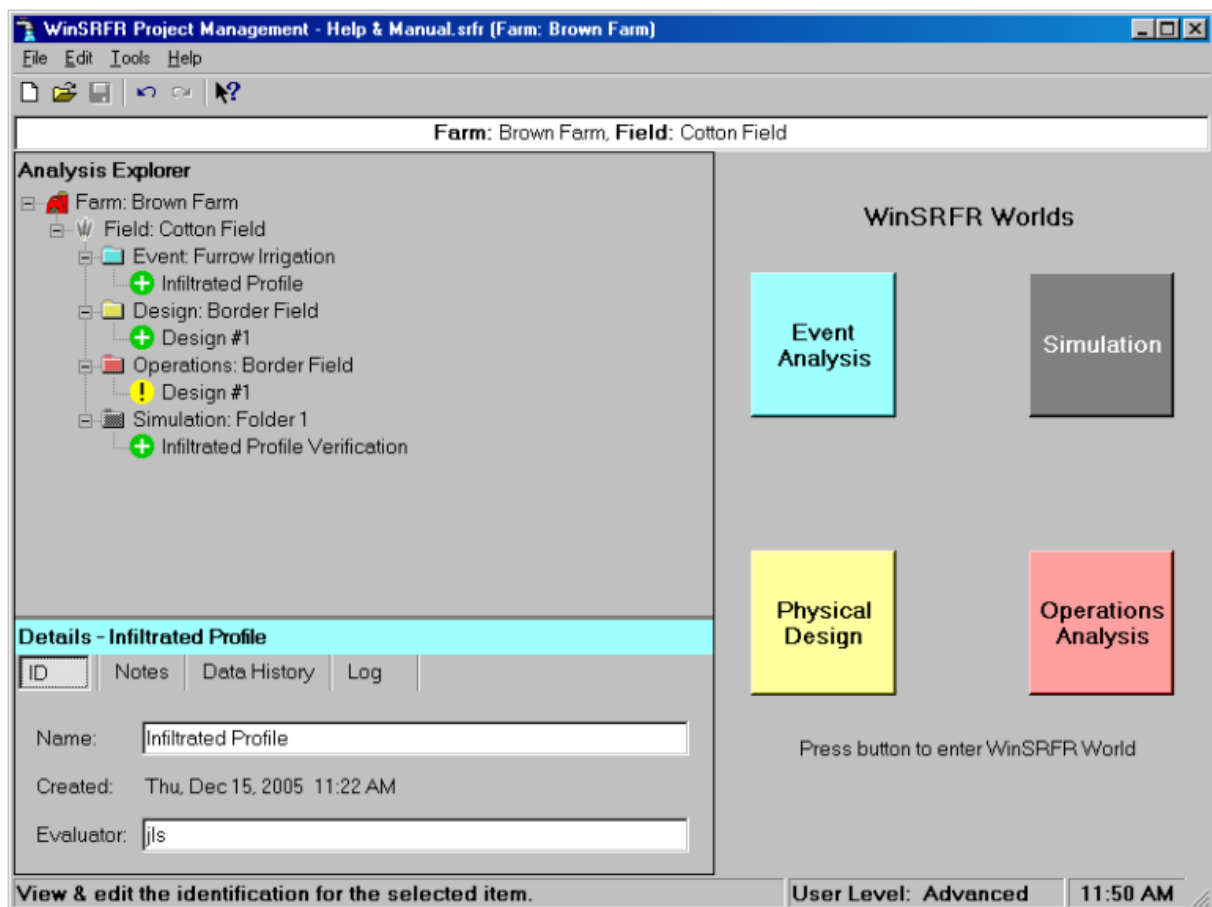


Figure 1.1 - WinSRFR Project Management Window

WinSRFR combines the functionality of BASIN, BORDER and SRFR with new capabilities, into four color-coded Worlds:

- Event Analysis World - New irrigation event analysis functionality
- Physical Design World - BASIN and BORDER's design functions
- Operations Analysis World - BASIN and BORDER's operations and management functions
- Simulation World - SRFR's simulation functions

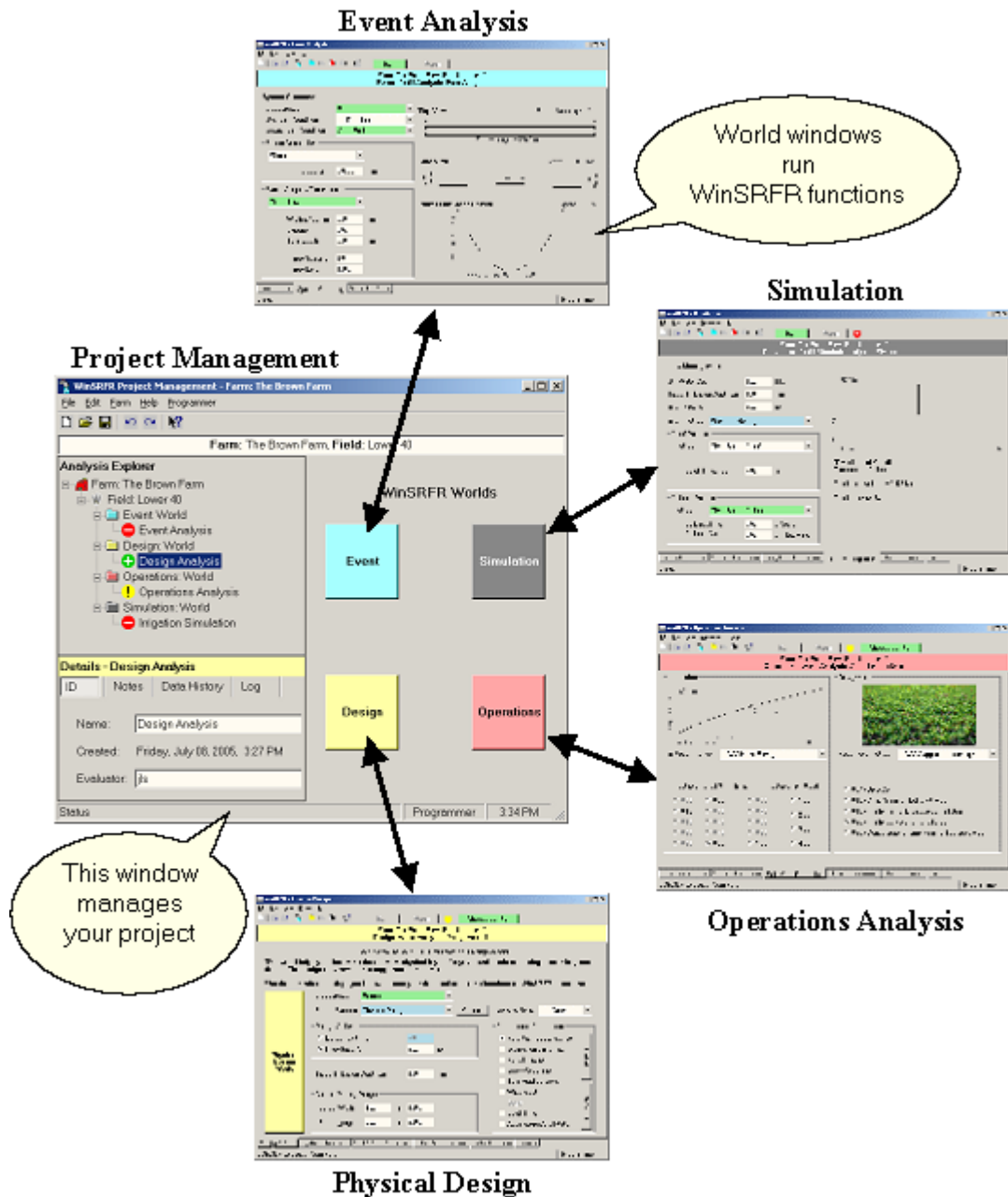


Figure 1.2 - WinSRFR Four Worlds of Functionality

## 1.1 Getting Started

WinSRFR is developed and supported by:

USDA – United States Department of Agriculture  
ARS – Agricultural Research Service  
ALARC – Arid-Land Agricultural Research Center

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### 1.1.1 Operating System and Hardware Requirements

WinSRFR is a Windows application implemented using Microsoft's .NET Framework 1.1. WinSRFR was built on the ported design, operations and simulation functionality from BASIN, BORDER & SRFR legacy DOS applications developed by the USDA-ARS (at the former US Water Conservation Laboratory). The User Interface (UI) was updated to take advantage of the current Windows capabilities, but the analytical procedures are the same as those of the legacy applications.

WinSRFR requires the following minimally configured PC for acceptable operation:

#### Supported Operating Systems

Windows XP  
Windows 2000

#### Additional Software Requirements

Microsoft's .NET Framework 1.1 (Installed by WinSRFR Installer if necessary)  
WinSRFR has not been tested with .NET Framework 2.0.

#### Storage Requirements

20 MB for the program. Project files can each be several MB in size.

#### Monitor

800 x 600 or larger resolution

All windows and dialog boxes provided by WinSRFR fit within an 800 by 600 pixel rectangle. This allows WinSRFR to be run on monitors capable of displaying 800 by 600 resolution or better. Most windows can be resized and, when operated in the Graphics Only view mode, all graphical results automatically scale to fit the available space.

## 1.1.2 Installation / Uninstallation

### Installation

WinSRFR must be installed using the installation program **ALARC WinSRFR Setup.exe**, which will decompress all needed files, register libraries with the Windows operating system, and create needed directories. By default, the program will install under the C:/Program Files folder and create a /USDA/WinSRFR xx.xx subdirectory, where xx.xx is the version number. Other USDA-ARS developed software may also install under the folder /USDA.

### Uninstallation

The program must be uninstalled using the Add/Remove Programs command under the Windows Control Panel, in order to correctly unregister the application and all its associated files.

## 1.1.3 Accessibility Issues

WinSRFR is designed to meet the accessibility guidelines set forth in the Certified for Windows logo handbook:

- Support standard system size, color, font, and input settings. This provides a consistent user interface (UI) across all applications on the user's system.
- Ensure compatibility with the High Contrast option for users desiring a high degree of legibility. When this option is selected several restrictions are imposed upon the application. For example, only system colors selectable through Control Panel or colors set by the user may be used by the application.
- Provide documented keyboard access to all features. This allows the user to interact with the application without requiring a pointing device, such as a mouse. See [Keyboard Navigation](#).
- Provide notification of the keyboard focus location. It should always be apparent both to the user and programmatically which part of the application has the focus. This requirement also enables use of the Magnifier and Narrator accessibility aids.
- Convey no information by sound alone. Applications that convey information by sound must provide other options to express this information.

All windows and dialog boxes provided by WinSRFR fit within an 800 by 600 pixel rectangle. This allows WinSRFR to be run on all monitors capable of displaying 800 by 600 resolution or better. Most windows can be resized and, when operated in the Graphics Only view mode, all result graphs automatically scale to fit the available space.

WinSRFR has been tested with these Microsoft supplied accessibility aids:

- **Magnifier** - Magnifies a portion of the computer's desktop for easier viewing
- **Narrator** - Reads the names, values and actions associated with displays and controls



### 1.1.4 Credits and Acknowledgements

Mr. James Schlegel was the lead programmer for the WinSRFR development project.

The unsteady flow simulation engine was developed by Dr. T.S. Strelkoff.

Basin design and operational procedures were developed by Dr. A.J. Clemmens, Dr. A.R. Dedrick, and Mr. R. J. Strand.

Border design and operational procedures were developed by Dr. T.S. Strelkoff, Dr. A.J. Clemmens, Mr. B.V. Schmidt and Mr. E. J. Slosky.

WinSRFR routines for event analysis were developed by Dr. E. Bautista and Dr. A.J. Clemmens.

USDA-NRCS provided significant input and feedback during the development of this software package. In particular, USDA-ARS acknowledges the contributions of Mr. Clarence Prestwich, Irrigation Specialist, National Water & Climate Center, USDA-NRCS.

### 1.1.5 Disclaimer

The software can be used to analyze both practical and theoretical irrigation problems. Analytical procedures are based on mathematical representations of irrigation systems, using a combination of physical principles and empirical relationships. Users need to interpret results judiciously, however, as they depend on uncertain inputs and assumptions that may be violated in the field. The United States Department of Agriculture and the Agricultural Research Service accept no liability or responsibility of any kind resulting from installation and use of this software.

## 1.2 Irrigation Analysis Overview

WinSRFR organization and functionality were defined based on the analytical process typically followed when examining surface irrigation hydraulic problems.

The first step in the process is an evaluation of current performance. The analysis, based on field-measured data, determines the fate of the irrigation water: how much water was applied, how much contributed to satisfy the requirements, e.g., to replace the soil water deficit, and how much was lost by deep percolation and runoff. For these studies, data from one or more observed irrigation events needs to be organized, represented graphically, and summarized. The evaluation may also be used to generate estimates of infiltration parameters, needed to determine infiltration distribution, and those parameter values have to be validated. The analysis generates performance measures and helps identify operational and/or design factors that may be affecting performance.

The next step in the process is a comparison of alternative operational scenarios. Using simulation tools or procedures such as those described in the NRCS design guides, the analyst needs to predict the irrigation system's performance as a function of operational variables (discharge rate, application time). This can be done manually, by trial-and-error, or automatically, if computer tools are available for conducting repeated computations across a range of values for the variables of interest. The analysis may produce an operational recommendation for the assumed average field conditions (infiltration, roughness, target application depth) or may suggest the need for an alternative design.

In the latter case, the analysis may examine the performance under an alternative layout. This may include changes in field slope (if soil conditions allow) and field dimensions (length and width). Again, simulation or accepted engineering procedures need to be applied to perform these types of analyses, based on expected average field conditions.

For both operational and design studies, and because field conditions vary during the irrigation season, sensitivity analyses need to be conducted to assess how performance will degrade with likely variations in system inputs relative to the design values. If performance proves too sensitive, then additional design or operational analysis will have to be conducted, to identify an alternative recommendation (design or operation) that is more robust (i.e., a recommendation that may attain a lower performance level but that may be less sensitive to possible deviations in field conditions from the design values).

Given this process, WinSRFR was designed with two important organizational features. First, WinSRFR has four major defined functionalities. These functionalities, referred to as Worlds in the software, are Event Analysis, Operation Analysis, Physical Design, and Simulation. These functions are explained in later sections. The second organizational feature is that scenarios run with these functions are stored in separate data folders. This structure organizes the data into logical groups and allows outputs generated in one World to be used as inputs in a different World (as well as using the same inputs in different Worlds).

## 1.3 Hydraulic Analysis Overview

This section summarizes the hydraulic analysis capabilities of WinSRFR's Event Analysis, Simulation, Physical Design, and Operation Analysis Worlds. Except for the Event Analysis World, WinSRFR's capabilities are based on those provided by the legacy programs SRFR, BORDER and BASIN programs. Detailed technical descriptions of the procedures employed in this application are provided in various technical references, several of which are provided with this software as PDF help files.

### 1.3.1 Event Analysis

Procedures in the Event Analysis world are used to evaluate the performance of irrigation events from field measured data and to estimate infiltration parameters needed for evaluation, simulation, physical design, and operational analysis. These procedures use physical principles, particularly a mass balance, to determine the disposition of the irrigation water. Three evaluation procedures currently are provided:

- Infiltration profile analysis from probe penetration data
- Merriam-Keller analysis of advance and recession data (Merriam and Keller, 1980)
- Elliot and Walker's (1982) two-point method analysis of advance data

Probe penetration analysis is an evaluation technique that relies on measurements of the post-irrigation depth of the infiltration wetting front. This depth is determined by driving a metal probe through the wetted profile at several locations along the field, and is applicable in heavy to medium-textured soils. The water penetration depth is used to estimate the post-irrigation depth of infiltration water  $d$  contributing to the irrigation target,  $D_{req}$ .  $D_{req}$  is calculated considering the depth of water needed to replace the root zone soil water deficit and water needed to meet the leaching and other requirements. The analysis requires measurements of inflow and outflow, a description of the root zone's available water capacity, and pre-irrigation soil water deficit. The applied and outflow volumes (for open-ended systems) are used to calculate a post-irrigation mass balance. Output of the analysis are: a) the applied, runoff, and infiltrated depth totals; b) infiltration depth profile; and; c) performance measures, including application efficiency and uniformity.

The Merriam-Keller procedure is a method for estimating the infiltration depth profile from a post-irrigation mass balance. The method can be applied to basins, borders, and furrows. The method matches the observed infiltration volume, calculated from the difference of measured inflow and outflow, with the numerical integral of the post-irrigation longitudinal infiltration depth profile. Infiltration depth at discrete points along the field is calculated from observed intake opportunity times, computed from the measured advance and recession times. Originally, the method used the resulting mass balance relationship to solve for the constant  $k$  of the Kostiakov infiltration, with the exponent  $a$  given from ring infiltrometer measurements or experience. WinSRFR implements the Merriam-Keller procedure using the Extended Kostiakov infiltration equation; therefore the user must additionally enter estimates of the final, steady state term  $b$  and the storage term  $c$  (or set them to zero, if the Kostiakov equation is preferred) in order to solve for the constant  $k$ . In addition to the outputs described above, the analysis produces an estimate of the field's infiltration function. The accuracy of the estimated function can be verified via simulation. A trial-and-error approach needs to be used to determine the combination of parameters (the given  $a$ ,  $b$ ,  $c$  and the resulting  $k$ ) that will most closely reproduce the observed advance and recession trajectories, and the observed runoff hydrograph, if one was measured.

Elliott and Walker's Two-Point Method is a procedure for estimating the  $k$  and  $a$  parameters of the extended Kostiakov equation from two advance time observations. The method was developed for

sloping furrow irrigation. WinSRFR's implementation of the method allows the user to apply it to sloping borders as well. The method uses the two observed advance times to set up two mass balance equations. Such equations require estimates of the volume of water stored in the surface during advance. Those estimates are generated by the procedure, under the assumption of normal depth at the measured advance times. WinSRFR will check if the normal depth assumption is applicable and will not complete the analysis if the assumption is invalid under the field conditions. The analysis does not require a measured hydrograph, but at least an estimate of the Extended Kostiakov steady state infiltration rate term  $b$  is needed in order to calculate  $k$  and  $a$  ( $c$  is assumed equal to zero). Inputs required by the analysis are; a) the measured inflow; b) advance times to two distances along the field (half the field length and full field length are strongly recommended); c) the measured outflow or an estimate of the steady state infiltration rate; d) an estimate of the Manning roughness coefficient, which is used to calculate normal depth; and e) for furrows, a description of the furrow cross sectional area (side slope and bottom width for trapezoidal furrows, power constant and exponent for parabolic shaped furrows). Outputs of the analysis, as indicated before, are  $k$  and  $a$ . If runoff measurements are available, then the function can be validated via simulation. In such cases, a trial-and-error approach is recommended to find the function that will best match the observed irrigation event, based on adjusting the value of  $b$ .

### 1.3.2 Simulation

SRFR solves the unsteady open-channel flow equations coupled with empirical equations describing infiltration and channel roughness. The partial differential equations of unsteady open-channel flow represent the physical principles of conservation of mass and momentum. Given the relatively low velocities and Froude numbers that characterize surface irrigation flows, SRFR uses simplified forms of the momentum equation. Such a modeling approach is nearly as accurate as using the full unsteady equations, if used under the right conditions, but is more robust and computationally faster. The zero-inertia (equilibrium) version accounts only for pressure gradient, friction, and gravitational forces acting on the flow. This form of the equations can be applied to all practical field conditions. The kinematic-wave version ignores the pressure gradient force and assumes that frictional forces are in balance with gravitational forces, i.e., that flow is at normal depth everywhere. Such an assumption is reasonable with relatively large slopes and only when there are no backwater effects (i.e., is applicable only to open-ended systems). SRFR automatically determines which model to use under the given conditions, but the user can override the kinematic-wave option (i.e., the user can use the zero-inertia option in cases where the kinematic-wave approach is applicable, but cannot specify the kinematic-wave option if that method is inapplicable).

Infiltration can be calculated from physical principles and surface irrigation models have been proposed that couple physical infiltration equations to the unsteady flow equations. Those models are mathematically delicate and presently impractical except for fundamental scientific studies. At this time, SRFR uses empirical infiltration relationships, with the specific functional form selected by the user. The basic Kostiakov power law and some variations are provided by SRFR.

SRFR can be configured to model basins, borders, and furrows, but it is a one-dimensional simulation model -- it assumes that all flow characteristics vary only with distance along the main direction of flow (longitudinal distance) and time, but not across the field width. For borders and basins, the model is applicable to situations where field properties and system inputs vary negligibly across the field width, e.g., negligible cross slope, uniform infiltration and roughness, and uniform inflow. In the case of furrows, simulations consider only single furrows and, therefore, neighboring furrows are assumed identical. Any variation in properties from furrow to furrow within a field must be modeled separately.

The results of a simulation, like those of an actual run in the field, depend on the hydraulic properties of the soil and crop (infiltration and roughness), the geometrical configuration of the system (length, cross-section, slopes, etc.), and system operation (flow rates, duration). Performance estimates depend also on the target infiltration depth for the irrigation. Users can assign constant field properties like the infiltration characteristics and roughness, bottom slopes, and furrow cross sections, or can prescribe variations in these properties with distance along the flow direction, and with inundation time. The user needs to specify all these inputs for the simulation to be performed. Simulation results include the advance and recession curves, flow and depth hydrographs at specified locations, water surface profiles at specified times, and a variety of performance measures such as application efficiency, distribution uniformity, and adequacy of the irrigation.

### 1.3.3 Physcial Design

Design involves finding one or more field configurations (length and/or width) that will yield acceptable levels of performance for the given field slope, soil and crop characteristics and available inflow. The analysis requires simulation results from different combinations of the design variables. The BASIN and BORDER programs were designed for that purpose, the former dealing with level basins and the latter with open-ended sloping borders. The procedures programmed in those applications have been adopted unmodified in WinSRFR.

Rather than making repeated calls to the simulation engine, the BASIN and BORDER design procedures calculate pertinent performance measures by interpolation, from static tables of simulation results. The tabular results are based on solutions of the unsteady flow equations in non-dimensional form. The non-dimensional equations reduce the dimensionality of the problem (i.e. reduce the number of input variables) and allow us to represent hydraulically related classes of irrigation problems based on a single simulation. Results are accurate relative to those obtained directly from simulation and computations are extremely fast.

Even with a dimensionless system of equations, irrigation problems depend on many inputs. The original BORDER and BASIN databases represent thousands of simulations covering practical ranges of the input variables. Similar tables have not been developed for low-gradient, closed-ended border irrigation or any type of furrow irrigation system. Therefore, at this time, design analysis is restricted to level-basin and open-ended sloping border irrigation. Furthermore, the analysis is restricted to the range of input variables contained in the tables of simulation results. Users have reported field conditions that are not covered by the existing dimensionless databases.

WinSRFR consolidates the design procedures of BASIN and BORDER in the Design World. The design procedures are quite different, partly due to hydraulic considerations, but also due to the independent analytical approaches adopted in the development of the legacy programs.

For level-basin systems, which have zero slope and runoff, the design is constrained by theoretical performance limits: for a given set of conditions, there is a field length beyond which impractically large inflow rates coupled with very small times of cutoff would be required to maintain a target performance level. This combination would require streams to "coast" (advance without inflow) for so long after cutoff that reaching the end of the basin becomes problematic, with even slight deviations from the assumed infiltration and roughness. Given pertinent field input and a target performance level (distribution uniformity based on the minimum depth in the distribution,  $DU_{min}$ ), the level-basin design procedures treat this length as an upper limit, with shorter basins and commensurate widths stemming from practical field considerations. The solution, e.g. a recommended length and width given an available inflow rate, will match the minimum application,  $D_{min}$ , with the irrigation requirement,  $D_{req}$ .

Theoretical performance limits similar to those for level basins cannot be readily defined for graded, open-ended border irrigation systems. With borders, distribution uniformity gains obtained through increased inflow rate are ultimately offset by increasing runoff losses. And rather than identifying a specific solution with a given performance level, the border design procedures generate a series of performance and management-variable contours that allow the user to examine the tradeoffs amongst design-variable combinations. As in the level-basin case, border design analysis can be based on  $DU_{min}$ , but it can also be based on the low-quarter distribution uniformity,  $DU_{lq}$ . In this case, the design matches the low-quarter average applied depth,  $D_{lq}$ , with  $D_{req}$ . Contours produced by the border-design procedures include Potential Application Efficiency (*PAE*) and Distribution uniformity (*DU*) based on either minimum or low quarter depth, runoff and deep percolation losses, and the ratio of cutoff time to advance time.

Performance and management contours can also be developed for level-basin design but this option was not considered at the time that BASIN was programmed. It may be considered in future versions of WinSRFR.

### 1.3.4 Operational Analysis

Operational analysis is similar to design analysis, except that the configuration is fixed while operational variables (discharge and cutoff time/distance) are unknown. Thus, the analysis requires simulation results from different combinations of the operational variables. WinSRFR's operational analysis routines currently are those available in BASIN and BORDER and, therefore, the analysis is limited to level-basins and graded open-ended border systems with the computational approach the same as for physical design (interpolation amongst tabulated results).

Operational analysis for level basins parallels the corresponding level-basin design procedures. For the given inputs, for example length, width, and available inflow rate, the procedures will identify a cutoff time that will just meet  $D_{req}$  and the corresponding  $DU_{min}$ . Alternative solutions can be found depending on user-specified constraints. For example, the analysis may specify an advance distance at cutoff, in which case the operational procedures compute a corresponding inflow rate and  $DU_{min}$ .

Similarly, operational analysis procedures for borders are conceptually related to the corresponding design procedures, except that the user does not specify  $D_{req}$  as fixed in the analysis. For a specified field configuration and soil and crop properties, the procedures generate performance contours as a function of discharge and cutoff time or discharge and cutoff location. Those performance contours cover a range of  $D_{req}$  with  $D_{min} = D_{req}$  or  $D_{lq} = D_{req}$ . The user then identifies that range of solutions that meet a specified  $D_{req}$ . That range can be identified by simultaneously viewing the performance contours with the Dynamic Water Distribution Diagram, which is described in section XX.

## 1.4 Creating and Using WinSRFR Projects

WinSRFR's User Interface is provided by a set of Windows and [Dialog Boxes](#).

[Project Management Window](#)

[Event Analysis World](#)

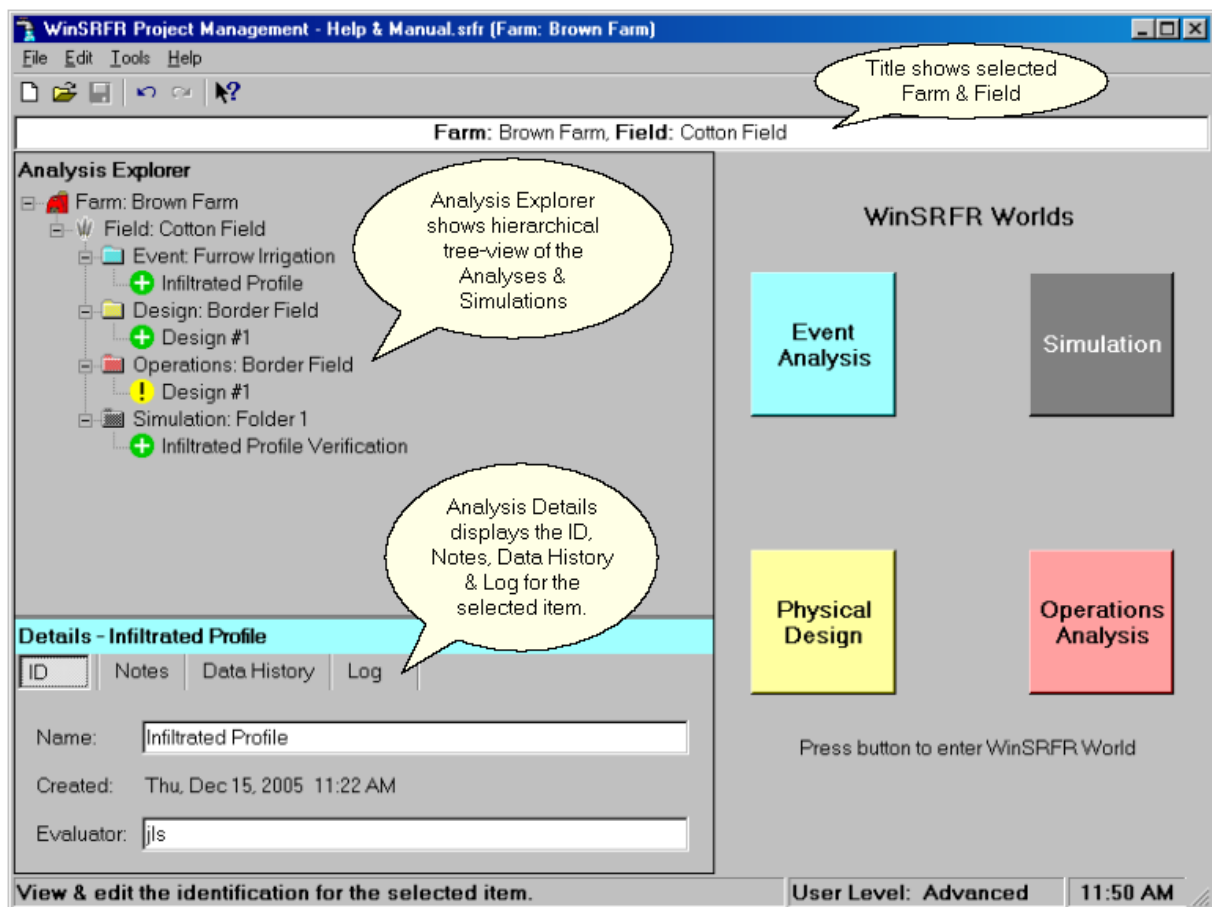
[Physical Design World](#)

[Operations Analysis World](#)

[Simulation World](#)

### 1.4.1 Project Management Window

The Project Management window is displayed when WinSRFR starts. This window is used to create and manage data within a particular WinSRFR project.



The three main components of the Project Management window are discussed in the following sections:

[Analysis Explorer](#)

[Analysis Details](#)

[WinSRFR Worlds Buttons](#)





#### 1.4.1.1 Analysis Explorer




The Analysis Explorer is the main tool for managing your WinSRFR Analyses & Simulations. It displays a hierarchical tree-view of the data within WinSRFR. The top three levels are merely containers; they help you organize your Analyses and Simulations that reside at the fourth (i.e. right-most) level. Refer to [Data Organization](#) for a discussion of WinSRFR's underlying data.

##### Containers

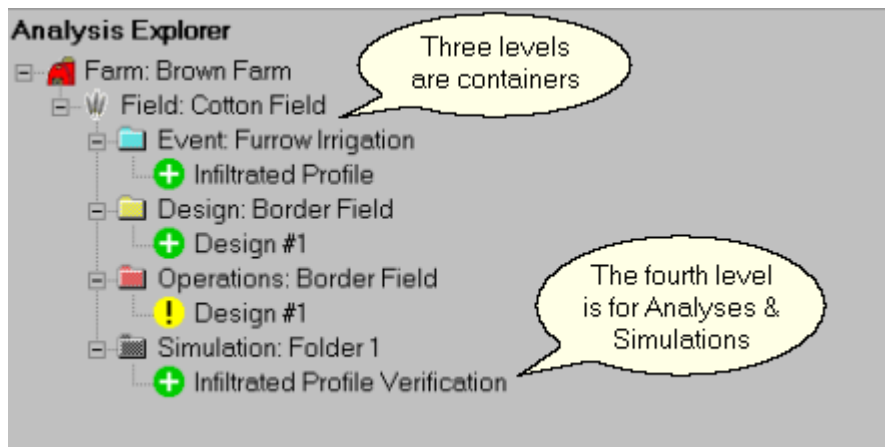
The top three levels within the Analysis Explorer help you organize your data within a WinSRFR data file (.srfr).

 **Farm: Brown Farm** - At the top is the Farm. Only one Farm is allowed per file so this level only appears once at the top of the tree. It lets you verify you have opened the correct file.

 **Field: Cotton Field** - At the next level (or branch) of the tree are the Fields. A Farm contains one or more Fields. The Field containers let you keep all Analyses and Simulation for each field in one location.

 **Event: Furrow Irrigation**  
 **Design: Border Field**  
 **Operations: Border Field**

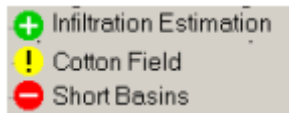
- At the last level of containers are the World Folders. These folders are associated with the WinSRFR Worlds used to run the contained Analyses or Simulations. This level lets you group your data by the type of analysis or simulation being performed. For example, you may want to perform several Event Analyses on the 1st Irrigation of a particular field. You would group these analyses together under an Event Analysis Folder under the Field as shown below.





## Analyses and Simulations

Your various Analyses and Simulations reside at the fourth level. An Analysis or Simulation is the complete collection of field data, run criteria and the subsequent WinSRFR run results. If you want to make several runs while varying one or more parameters and you want to save the results of all these runs, you will want to create individual Analyses or Simulations for each run. These can be grouped within one or more World Folders depending on your needs.



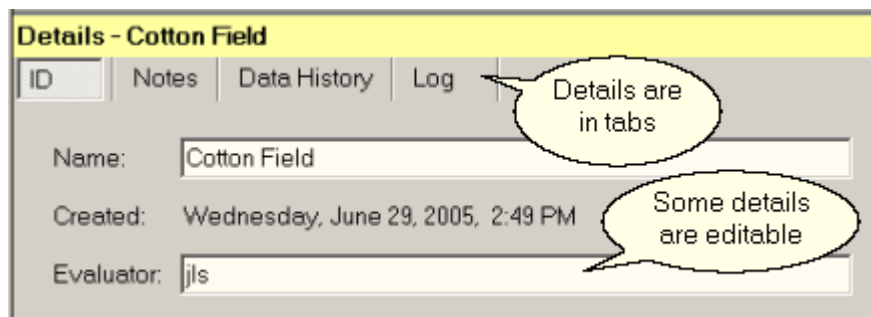
- The icon associated with an Analysis or Simulation shows the status of the Run Results. The green plus indicates complete results are available while the yellow exclamation point indicates results are available but not complete; another step is necessary to complete the results. The red minus indicates no results are available. Double-clicking the mouse on an Analysis or Simulation will display its corresponding [WinSRFR World](#). Pressing the Enter key will display the WinSRFR World window for the currently selected Analysis or Simulation (Cotton Field in the example above)

## Context Menus

All items in the Analysis Explorer have associated right-click context menus that provide access to functions for managing your WinSRFR data. Context Menus accessible using only the keyboard; a mouse is not required. See [Context Menus](#) and [Keyboard Navigation](#) for more details.

### 1.4.1.2 Analysis Details

The Analysis Details pane provides access to the identification (ID), Notes, Data History and Log for Analyses and Simulations. The details for folders are limited to ID and Notes.



**ID** - The name of the Farm, Field, World Folder, Analysis or Simulation. The name can be edited.

**Notes** - An area for extra information you want to remember related to the Farm, Field, World Folder, Analysis or Simulation.

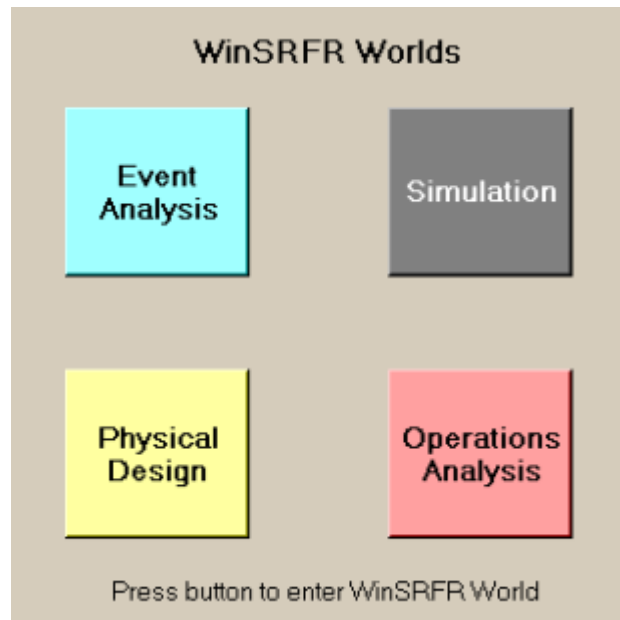
**Data History** - Tracks how an Analysis or Simulation was created. This data is not editable.

**Log** - A history of all Runs performed for this Analysis or Simulation. This data is not editable.

### 1.4.1.3 WinSRFR Worlds Buttons

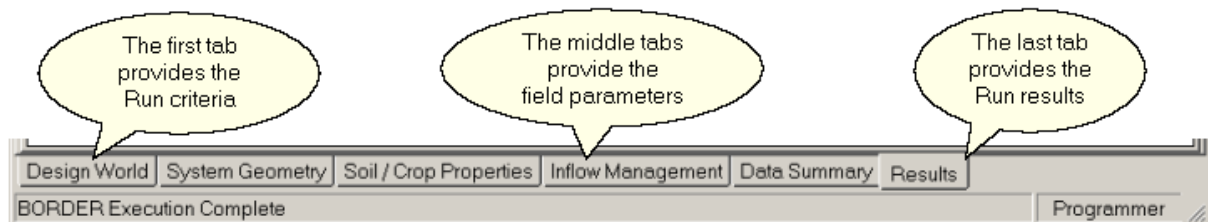
Access to WinSRFR's Worlds is provided by the [Project Management Window's Analysis Explorer](#) or by one of the its four colored-coded buttons. Pressing a button performs one of the following actions:

- 1) If no Analysis exists for that World, it will create one.
- 2) If only one Analysis for that World exists, it will be displayed.
- 3) Otherwise, you will be directed to use the Analysis Explorer to choose create or display.



### 1.4.2 WinSRFR World Tabs

The World Tab is the left-most tab for any World window ([Event](#), [Design](#), [Operations](#), [Simulation](#)). From this tab, the user can select the Irrigation system type (basin, border, or furrow) and the upstream and downstream boundary conditions. Upstream boundary conditions (No Drainback/Drainback) can only be specified for the Simulation World. For other Worlds, the analysis assumes No Drainback. World tabs also provide access to a World's upper level analytical options.

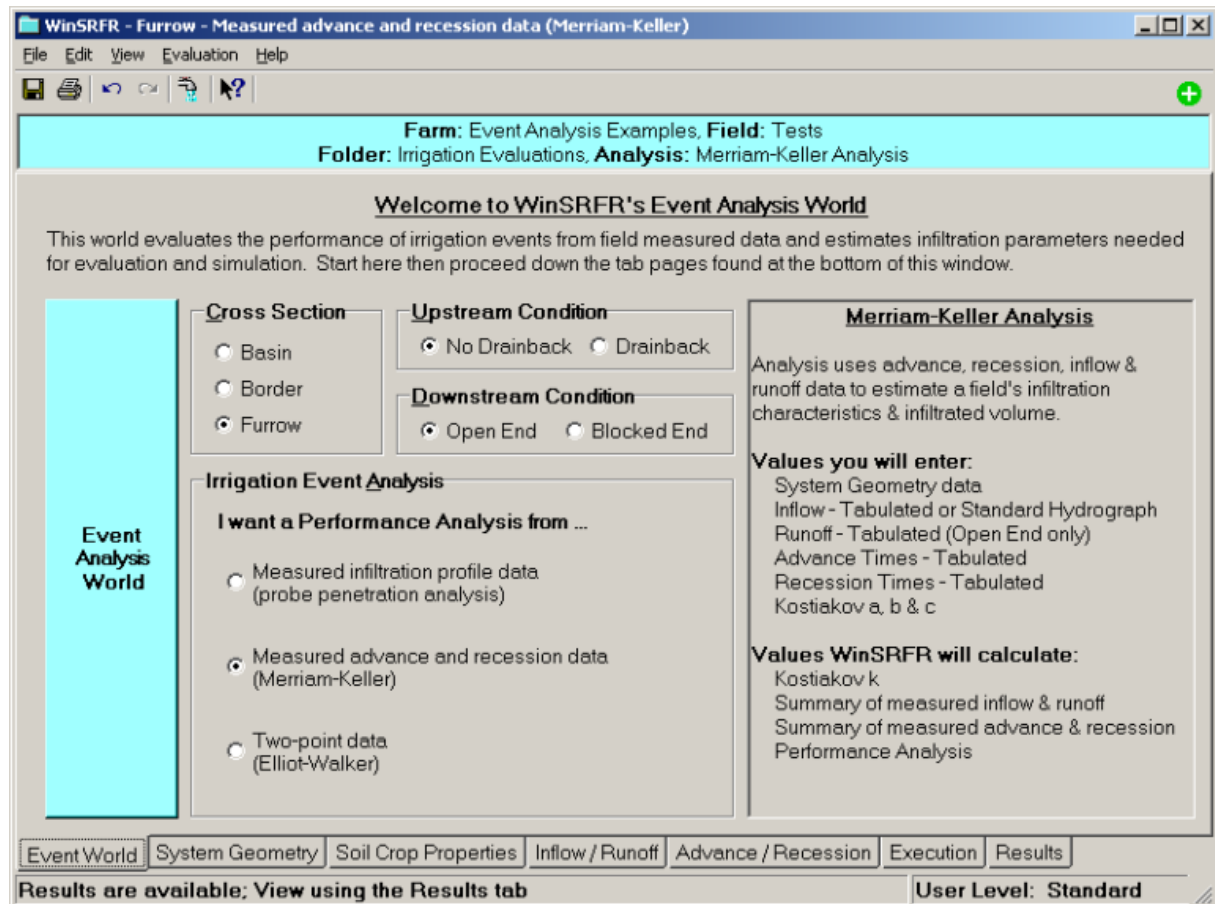


For example, for the Event Analysis World, the Irrigation Event Analysis option buttons are used to select the desired type of analysis (Probe Penetration, Merriam-Keller, or 2 Point Method Analysis). The tabbed form provides a brief description for the available analytical options. In the Physical Design World, selecting a Design Option provides feedback to the user relative to the type of analysis performed, the inputs that will be required, and the outputs that will be produced. Technical descriptions of these options are provided in the Common Task section.

### 1.4.2.1 Event Analysis World

The Event Analysis World helps analyze the performance of an irrigation using measurements taken before, during and after the irrigation. It can also provide estimates of infiltration parameters such as the Kostiakov  $k$ ,  $a$  &  $b$ . Supported analyses include:

- Performance analysis from measured infiltration profile (probe penetration analysis).
- Performance analysis from measured advance & recession data (Merriam-Keller analysis).
- Performance analysis from two-point advance data (Elliot-Walker analysis).



### Performance Analysis

All event analyses provide a Performance Analysis summarizing the efficiency & adequacy of the irrigation.

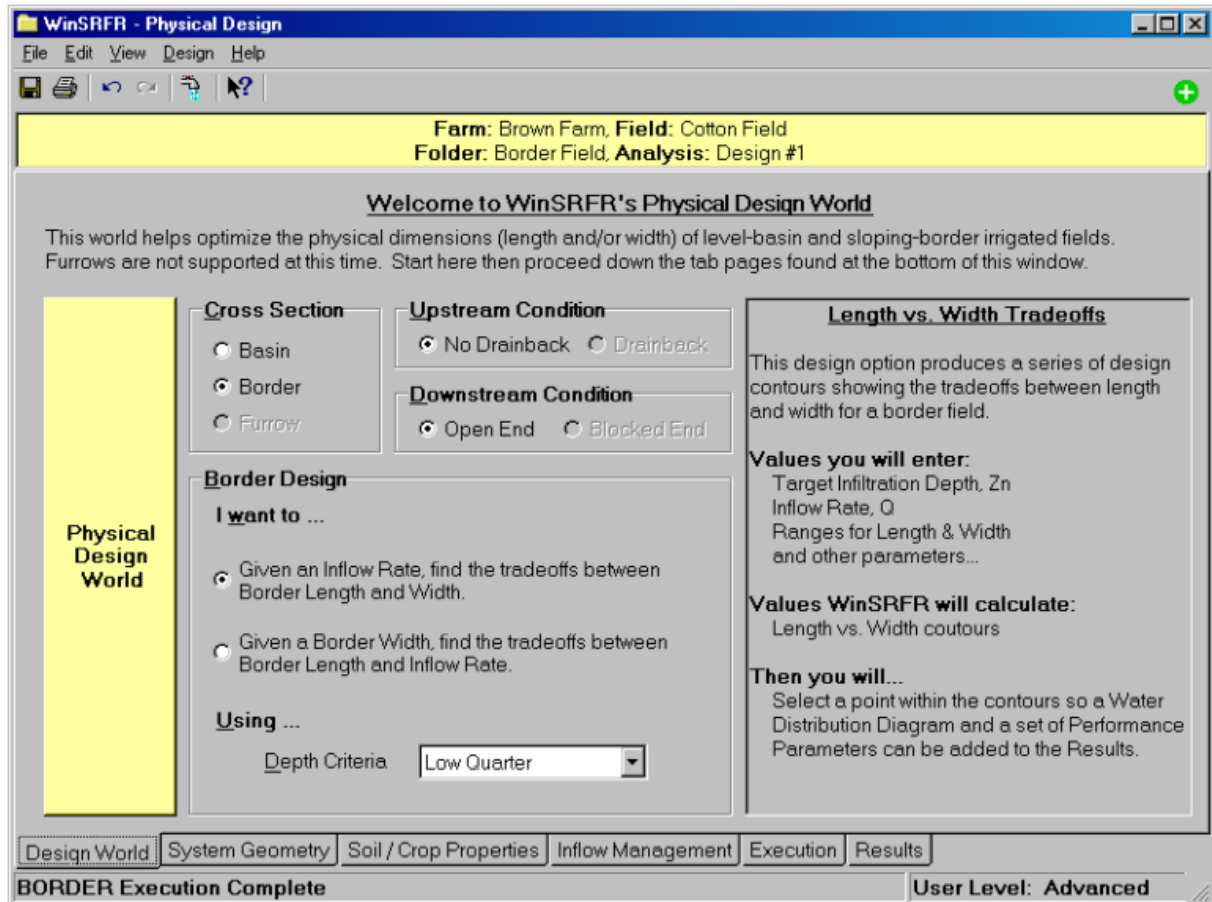
### Infiltration Parameter Estimation

Some event analyses estimate infiltration parameter based on the Modified Kostiakov Formula:  $Z_n = k \cdot T_n^a + b \cdot T_n$ .

- Merriam-Keller estimates Kostiakov  $k$  using advance / recession data and user estimates of Kostiakov  $a$ ,  $b$ , &  $c$ .
- Elliot-Walker estimates Kostiakov  $k$ ,  $a$  &  $b$  using two-point advance data.

### 1.4.2.2 Physical Design World

The Physical Design World helps optimize the **physical layout** of Basin and Border fields, specifically, the Length and/or Width of a field is calculated. Other irrigation parameters, such as Inflow Rate, may also be calculated but the distinguishing characteristic of the Physical Design World is the calculation of Length and/or Width.



After the physical layout is designed, the **operations** of the field's irrigation is supported by the [Operations Analysis World](#). The design of furrows is currently not supported; irrigation of furrows can be **simulated** using the [Simulation World](#).

#### Basin Field Design

The design of level-basins is based on [BASIN](#), a program previously developed by USWCL.

See the example: [Design a Basin Field](#)

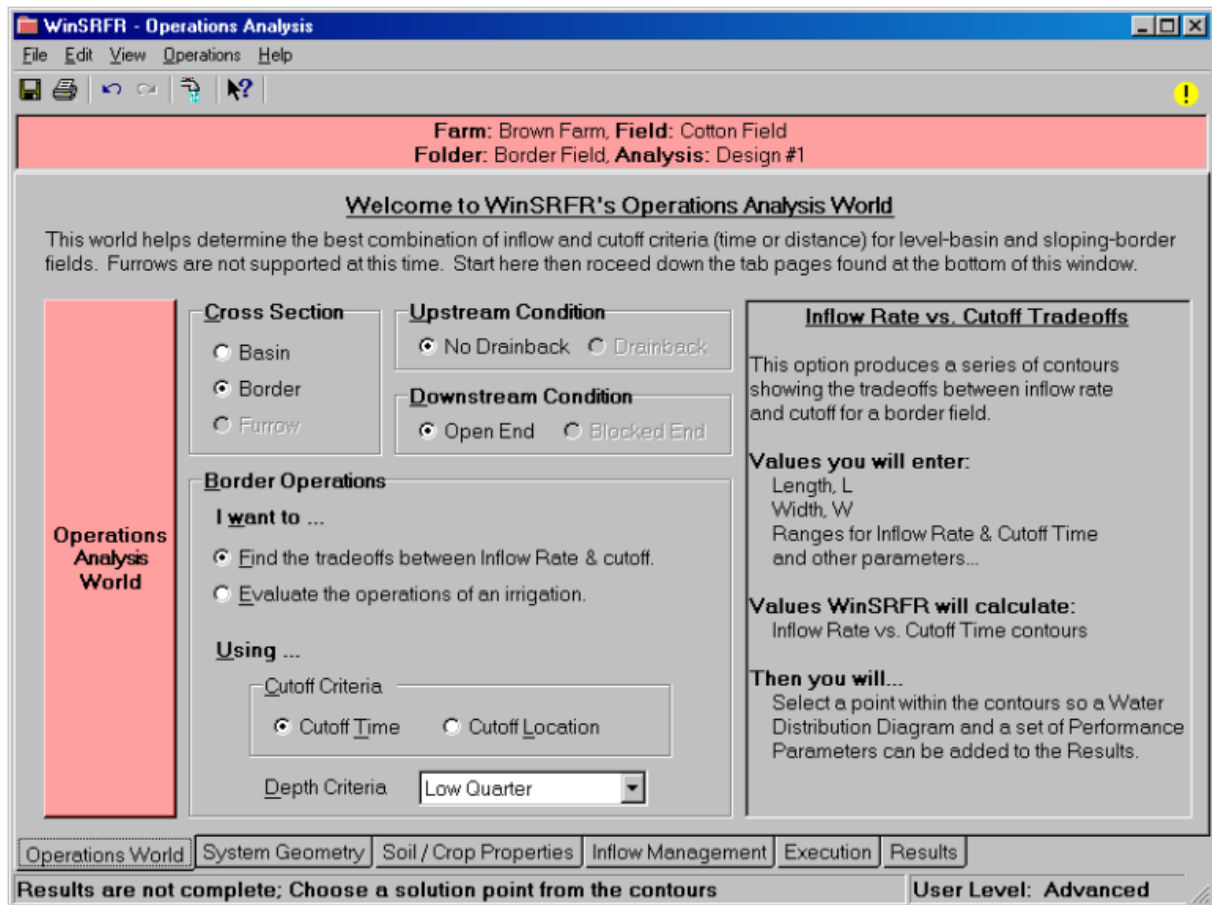
#### Border Field Design

The design of sloping-borders is based on [BORDER](#), a program previously developed by USWCL.

See the example: [Design a Border Field](#)

### 1.4.2.3 Operations Analysis World

The Operations Analysis World is used to optimize the **irrigation operations** for your Basin & Border fields. Some of the irrigation parameters calculated in this world are Inflow Rate, Cutoff Time and Cutoff Location.



After the operations have been defined using this world, the irrigation can be simulated using the Simulation World. The operations of furrows is currently not supported; irrigation of furrows can be **simulated** using the [Simulation World](#).

### Basin Field Operations

The operations of level-basins is based on [BASIN](#), a program previously developed by the USWCL.

See the example: [Operate a Basin Irrigation](#)

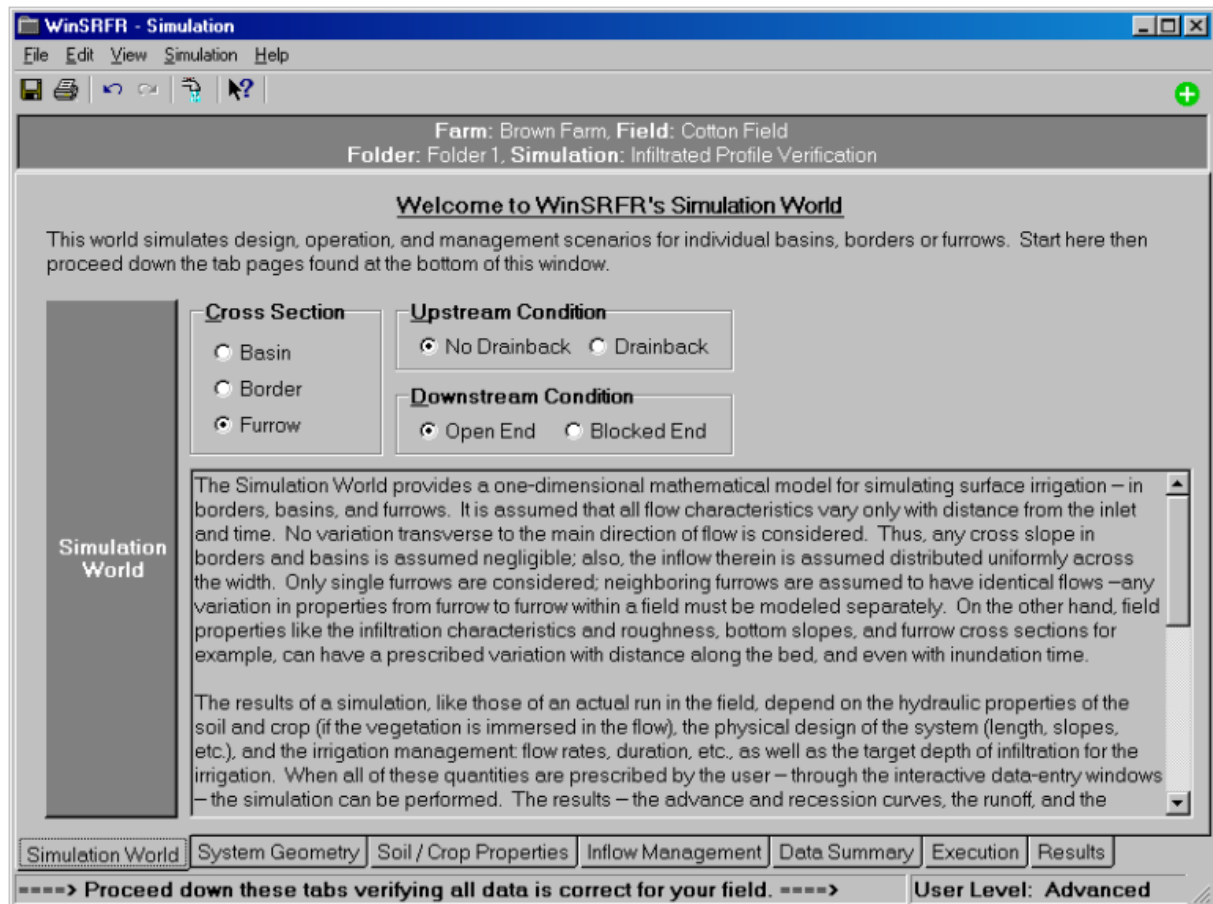
### Border Field Operations

The operations of sloping-borders is based on [BORDER](#), a program previously developed by the USWCL.

See the example: [Operate a Border Irrigation](#)

#### 1.4.2.4 Simulation World

After a field's **physical layout** is designed using the [Physical Design World](#) and the **operations** parameters are set using the [Operations Analysis World](#), its irrigation can be **simulated** using WinSRFR's Simulation World.



The simulation of basins, borders and furrows is based on [SRFR](#), a program previously developed by the USWCL.

#### Basin Irrigation Simulation

See the example: [Simulate a Basin Irrigation](#)

#### Border Irrigation Simulation

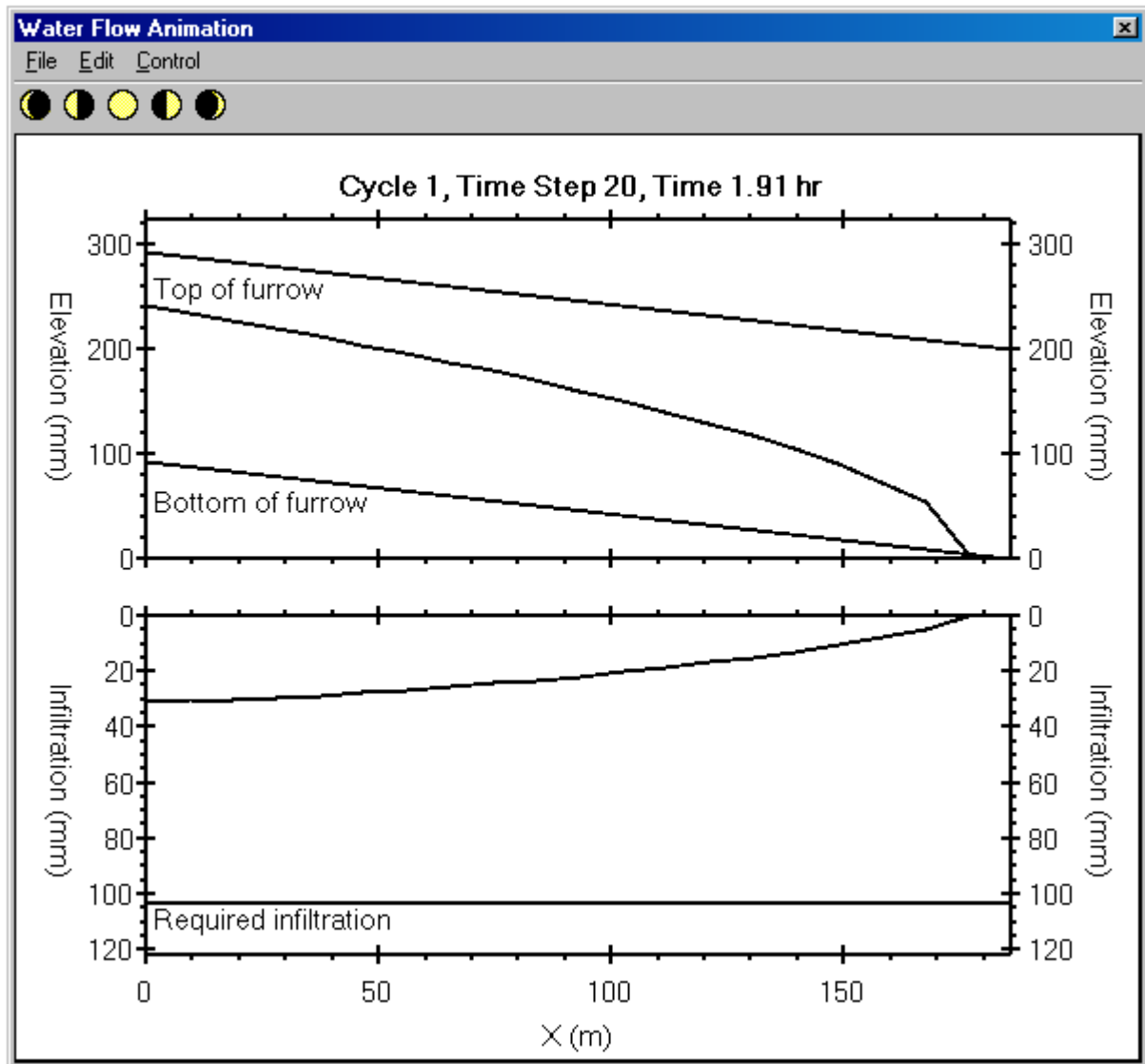
See the example: [Simulate a Border Irrigation](#)

#### Furrow Irrigation Simulation

See the example: [Simulate a Furrow Irrigation](#)

## Water Flow Animation

During the Simulation of an Irrigation, WinSRFR produces an animation of the irrigation water flowing over the field and into the soil. The automatic use of this animation view can be enabled and disabled using [User Preferences](#). It is always available under the Simulation Worlds' View menu.



The animation can be controlled much like a VCR. Use the Goto Start, Step Back, Play / Pause, Step Forward and Goto End buttons and menu items to move through the animation frames. At any time, the data in a frame can be copied to the clipboard as a bitmap for pasting into a Word document or as tab separated values for pasting into Excel.



### 1.4.3 Data Entry Tabs

The World Data Windows provide the interface for editing input data associated with a particular analysis and for viewing the corresponding results. All World Windows are organized similarly using tab controls, with each tabbed page representing a category of input or output data. There are two rows of tabs in a World Window, the lower one for inputs and the upper one for outputs. The last tab in the lower row provides the mechanism for switching between input and output tabs. Input tabs consist of the following:

- [World Run Criteria](#)
- [System Geometry](#)
- [Soil/Crop Properties](#)
- [Inflow Management](#)
- (Function Options)
- [Execution Control](#)
- [Run Results](#)

For a particular tab, for example System Geometry, the available input options will differ depending on the particular World. More details on these tabs are provided in the following. Output tabs vary depending on the particular World the user is working with, but consist of printable reports containing tabular and/or graphical data. Some of these output forms are described under [Common Tasks](#).

#### 1.4.3.1 System Geometry

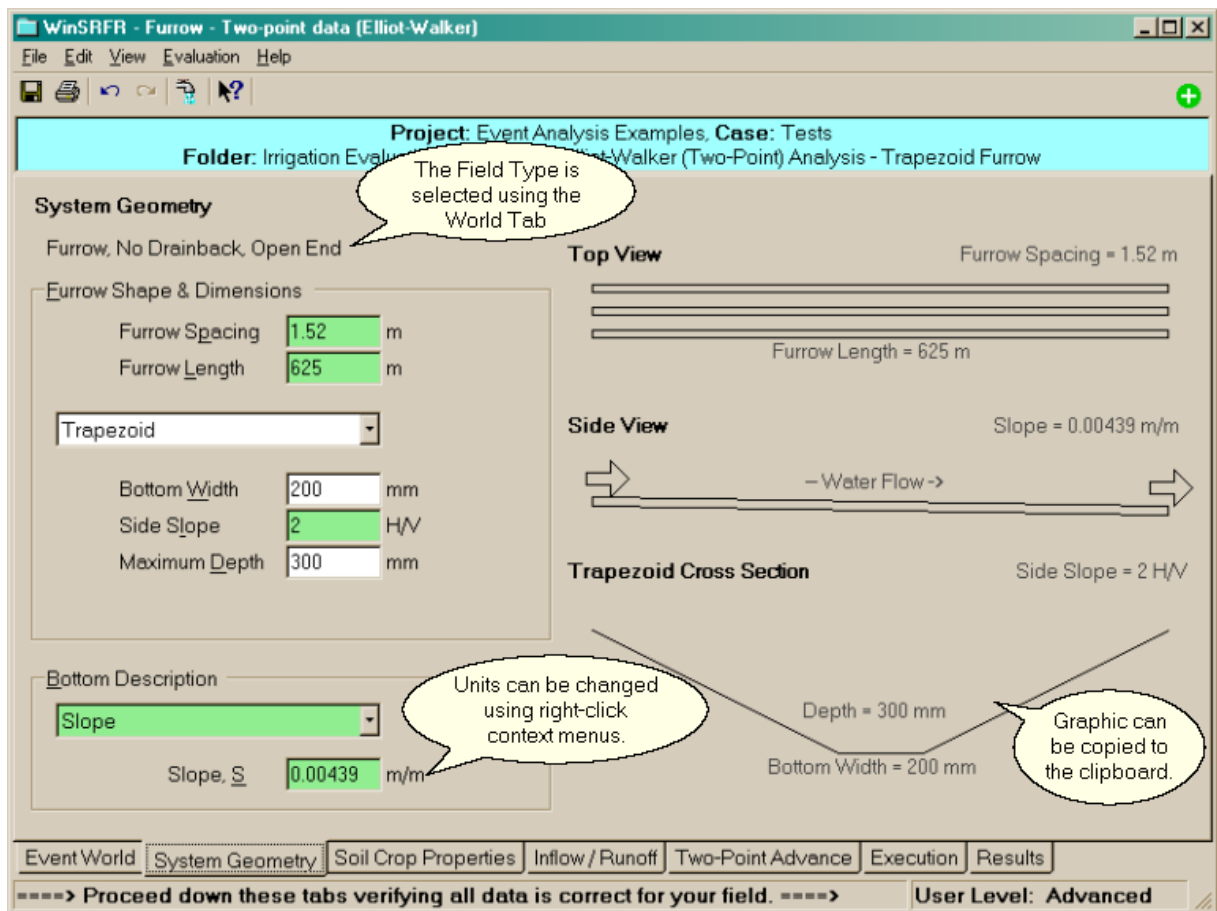
The System Geometry tab is used to define the irrigation system's geometrical layout. Because different types of analysis (Event, Design, Operations, Simulation) require different sets of geometrical inputs, the input controls displayed by the Geometry tab vary somewhat by World. In cases where a variable is an output of the analysis (e.g. Length, when designing a system), the input box displays either TBD (to be determined), or the output of the analysis (once the analysis is run). That value then is not user-editable.

**NOTE:** *In this tab as well as in other tabs, the expected unit system for a variable is displayed to the right of an input control. Default units are assigned to each variable depending on the unit system selected under User Preferences. For a particular session, you can modify the units of individual variables by right-clicking on the label and selecting an alternative from the displayed unit label list*

The System Geometry tab shows the physical layout of the basin, border or furrow being analyzed. What physical layout features are available is dependent on the WinSRFR World and **Field Type**. The Field Type, selected using the [World Tab](#), consists of:

- **Cross Section** (Basin, Border, Furrow)
- **Upstream Conditions** (Drainback, No Drainback)
- **Downstream Conditions** (Open End, Closed End)





Possible inputs provided by the System Geometry tab include:

- **Length** – length of the system along the direction of flow
- **Width/Furrow Spacing** - length of the system perpendicular to the direction of flow; width applies to basins and borders, furrow spacing to furrows. When dealing with furrows, the furrow spacing is used to compute the infiltrated depth (volume/length/width). Hence, when modeling a furrow system where every-other-furrow is irrigated, twice the nominal furrow spacing needs to be entered to calculate a representative average application depth.
- **Maximum Depth** – depth at which water will overflow. For borders and basins, it is the height of the berms. For furrows, it is the maximum depth used to compute the furrow's cross section. If the computed water depth at any point exceeds this maximum depth, the SRFR simulation engine will issue an OVERFLOW warning (see the output Summary Tab). In overflowing furrows, the assumption that neighboring furrows behave identically allows the simulation to proceed with lateral furrow boundaries midway between the given and adjacent furrows. These boundaries, while confining the furrow flow contribute nothing to surface roughness or infiltrations, as do the solid boundaries below. In furrows, the simulation is as realistic as the similarity between adjacent furrows. In borders or basins, the actual lateral loss of water to a neighboring, dry border strip or basin is not modeled when the same assumption as for furrows is applied. The user needs to reduce the inflow or the design (increase the berm height or furrow depth) to prevent an overflow from actually occurring in the field.

- **Bottom description** – WinSRFR provides five options for describing the field bottom. These are accessible using the Bottom Description drop-down list:
  - Slope – average field slope (Total vertical drop / Field Length). An input box will be displayed to enter the slope value. This is the only option displayed when working in the Physical Design or Operational Analysis Worlds, as the built-in procedures assume a constant slope.
  - Slope Table – Table of longitudinal distances vs. slope. Each entry in the table is a location where the average slope changes. Therefore, a slope value needs to be given at distance zero; the last entry is assumed to be the average slope in the last portion of the field. The Edit Table button appears when this option is selected. Pressing the button will launch the Slope Table dialog. This dialog box is described in more detail further below.
  - Elevation Table – Table of vertical field elevations vs. distance. Each entry in the table represents a surveyed elevation-distance pair. At a minimum, an elevation at the upstream and downstream end of the field needs to be entered and the downstream location needs to match the defined field length. As in the Slope Table, elevation values are edited using the Elevation Table dialog.
  - Average From Slope Table – This option computes an average slope from tabulated slope values. Tabular data needs to be entered as in the Slope Table option. After entering a Slope Table, the user can switch at any time between this option and the Slope Table option.
  - Average From Elevation Table – This option computes an average slope from tabulated elevations. Tabular data needs to be entered as in the Elevation Table option. After entering an Elevation Table, the user can switch at any time between this option and the Elevation Table option.
  
- **Furrow Shape and Dimensions** -This option is displayed only when the Furrow option is selected in a World Tab. Furrow cross-sectional area can be described generally using either a trapezoidal or parabolic section, hence options for defining furrow cross section are the following:
  - Trapezoid – a trapezoidal section is defined by two parameters, the Bottom Width and the Side Slope (Horizontal/Vertical). Input boxes for those two parameters will be displayed when the Trapezoid option is selected.
  - Power Law – a power law or parabolic section is defined by a relationship of the form  $TW = C * Y^M$  where TW is the top width, Y is the depth, and C and M are empirical parameters. The units of C depend on the units of Y and TW while M is dimensionless. When this option is selected, the user will need to enter m and the top width value at 100 mm (4 in). These values will be used to compute C.
  - Trapezoid from Field Data – This option allows the user to enter field data and to calculate the corresponding trapezoidal section parameters. An Edit Data button will appear when this option is selected. Pressing this button will launch the Enter/Edit Furrow Cross Section dialog, which is described further below.
  - Power Law from Field Data – This option is similar to the previous one, except that it launches the Furrow Cross Section dialog with power law options selected.

## Slope/Elevation Table Dialog

The [Slope and Elevation Dialogs](#) allow you to enter tabular data (distance vs. slope or distance vs. vertical elevation). There are three ways for entering data.

- **Manual Entry** – To manually enter data, you will need to add as many rows as needed to the default table (which will open with two rows). Use the Edit/Distances/Insert Rows Before (After) command to add rows. Alternatively, you can right-click the mouse over the leftmost part of the table (the grayed column at the left) to bring up a pop-up menu that will display the insert (and delete) row commands. When entering data, distances must be in increasing order.
- **Import/Export** - You can import values from a text file, using the Dialog's File/Import from Text File command. The file must contain two tab-separated columns of data. You can easily exchange data between projects by using the File/Export to Text File command to export data from an existing WinSRFR project to a text file and then importing those data into the new project.
- **Copy/Paste** – You can import spreadsheet data (Excel, Quattro Pro) using copy and paste. When importing spreadsheet data, existing tabular values will be replaced by the copy/paste operation. Therefore, the spreadsheet data must include at a minimum values at the head and end of the field. You can use copy/paste to transfer data from WinSRFR to a spreadsheet. When importing data, the top row in the spreadsheet data columns can contain unit labels.

**NOTE:** The grid control used to enter tabular elevation and slope data requires at least two values, at the upstream and downstream end of the field. Those locations cannot be edited. To edit the field length, use the corresponding input box in the Field Geometry Tab.

**NOTE:** The grid control used to enter tabular data (elevation, furrow cross section, tabulated hydrograph) does not respond to the Enter key when the cursor is at the last row position. Pressing Enter under those conditions will not enter the data. Therefore, when entering the last value (e.g. the last elevation), use the up arrow to move the cursor to the previous row. This will enter the data.

## Enter/Edit Furrow Cross Section Data Dialog

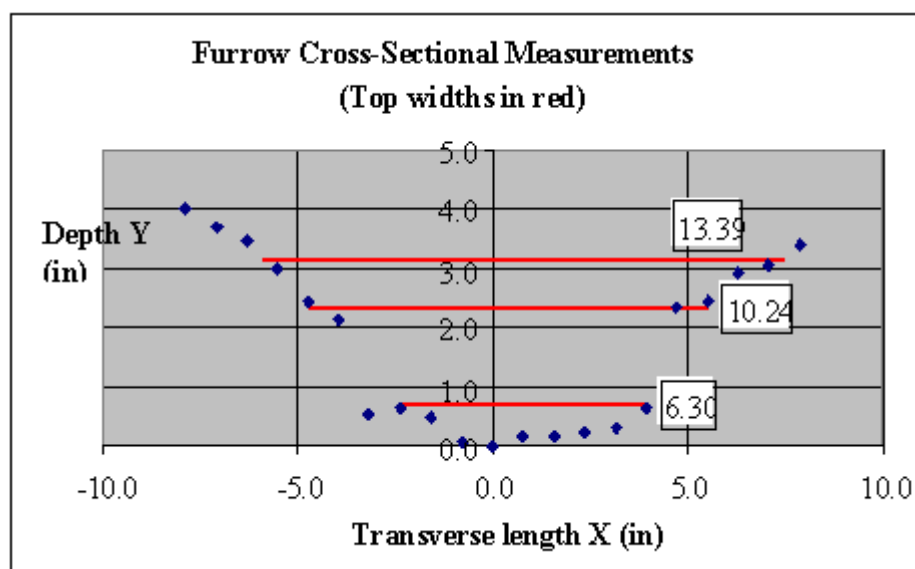
WinSRFR defines the cross section of a furrow as either a trapezoid or a power law function. These two methods are convenient for mathematical operations but may not be easy to define. The [Enter /Edit Furrow Cross Section Data dialog](#) box enables entering furrow cross section data as measured in the field. WinSRFR can 'best fit' these data to either a trapezoid or power law.

Three methods are available for defining furrow cross section data:

- **Depth / Top Width Table** - a series of furrow depth / top width pairs
- **Profilometer Table** - furrow depths as a function of transverse distance, as measured using a Profilometer.
- **Flow Cross Section** - a series of furrow depth / top width pairs, with depths given at the bottom, middle, and top of the furrow depth

These methods are explained with the help of Figures 1.4.3.1a – 1.4.3.1c, which depict typical furrow cross-sectional data and the resulting WinSRFR data entries. In Figure X1, the red horizontal lines represent top width measurements taken at three arbitrary depths, 0.71, 2.36, and 3.15 in. In the figure, the labels above or next to the red lines are the corresponding top width value. The symbols represent measurements of furrow depth (Y) vs. transverse distance (X) taken on a regular X-Y grid with a profilometer. In many field situations, the evaluator will take a few top width measurements at arbitrary depths. In such cases, the depth/top width option would be selected and the resulting table for the data of **Figure 1.4.3.1a** would be as given in **Figure 1.4.3.1b**. If detailed profilometer data are available instead, then the Profilometer option should be selected and the resulting table would be as given in **Figure 1.4.3.1c**. The Flow Cross Section option is similar to the Depth/Top Width option except that WinSRFR fixes the depths at the bottom, middle, and top of the furrow.

As with the tabular bottom elevation data, cross sectional tabular data can be entered manually, by importing a text file, or by copying/pasting from a spreadsheet. Notice that for this example, from **Figure 1.4.3.1a**, the vertical origin of the profilometer measurements is at the bottom of the furrow. However, the Dialog box expects data with the origin at the top of the furrow. If data is copy/pasted from a spreadsheet and those data have their origin at the bottom of the furrow, WinSRFR will make the necessary calculations to set the origin at the furrow top. Import and copy/paste operations will replace any existing tabular data so export any data that you need to save prior to making any changes.



**Figure 1.4.3.1a - Furrow Cross-Sectional Field Measurements**

The cross section data can be fitted to either a trapezoid or power law function, as defined by the Furrow Shape option. WinSRFR calculated furrow geometry parameters are displayed in blue but can be modified if a different fit is desired; modified values are displayed in green. Once the desired fit has been achieved, press the "Transfer ..." button to transfer this data back to the WinSRFR Analysis or Simulation. To exit the dialog box, press either the "Save Field Data & Close" button or the "Cancel" button. If you have modified any cross section field data, you should choose the "Save Field Data & Close" button. The "Cancel" button simply closes the dialog box with no further action; any changed values will be lost.

Enter / Edit Furrow Cross Section Data

File Edit Help

**Furrow Field Data**

Depth / Width Table — Fit To —> Trapezoid

Depth / Width Data


Set Depths to Top/Middle/Bottom

Depth / Width Table	
Depth (in)	Width (in)
0.71	6.3
2.36	10.24
3.15	13.39

Cross Section Area ( $\text{ft}^2$ ) = 0.306

**Furrow Shape**

Width Table Trapezoid



Trapezoid Furrow

Bottom Width (in) 4.12

Side Slope (H/V) 1.41

Max Depth (in) 3.15

Trapezoid Area ( $\text{ft}^2$ ) = 0.187

Transfer Trapezoid Data to Simulation

Save Field Data & Close Cancel Help

Figure 1.4.3.1b - Cross-Sectional Data Entered as Depth / Width Pairs

Enter / Edit Furrow Cross Section Data

File Edit Help

**Furrow Field Data**

Profilometer — Fit To —> Trapezoid

Profilometer Data

No. of Rods 21


Rod Spacing (in) 0.79

Profilometer Data	
Rod Location (in)	Rod Depth (in)
-7.9	0
-7.11	0.31
-6.32	0.55
-5.53	1.02
-4.74	1.57
-3.95	1.89
-3.16	3.46
-2.37	3.39
-1.58	2.54

Cross Section Area ( $\text{ft}^2$ ) = 0.263

**Furrow Shape**

Profilometer Trapezoid



Trapezoid Furrow

Bottom Width (in) 4.21

Side Slope (H/V) 1.39

Max Depth (in) 3.70

Trapezoid Area ( $\text{ft}^2$ ) = 0.241

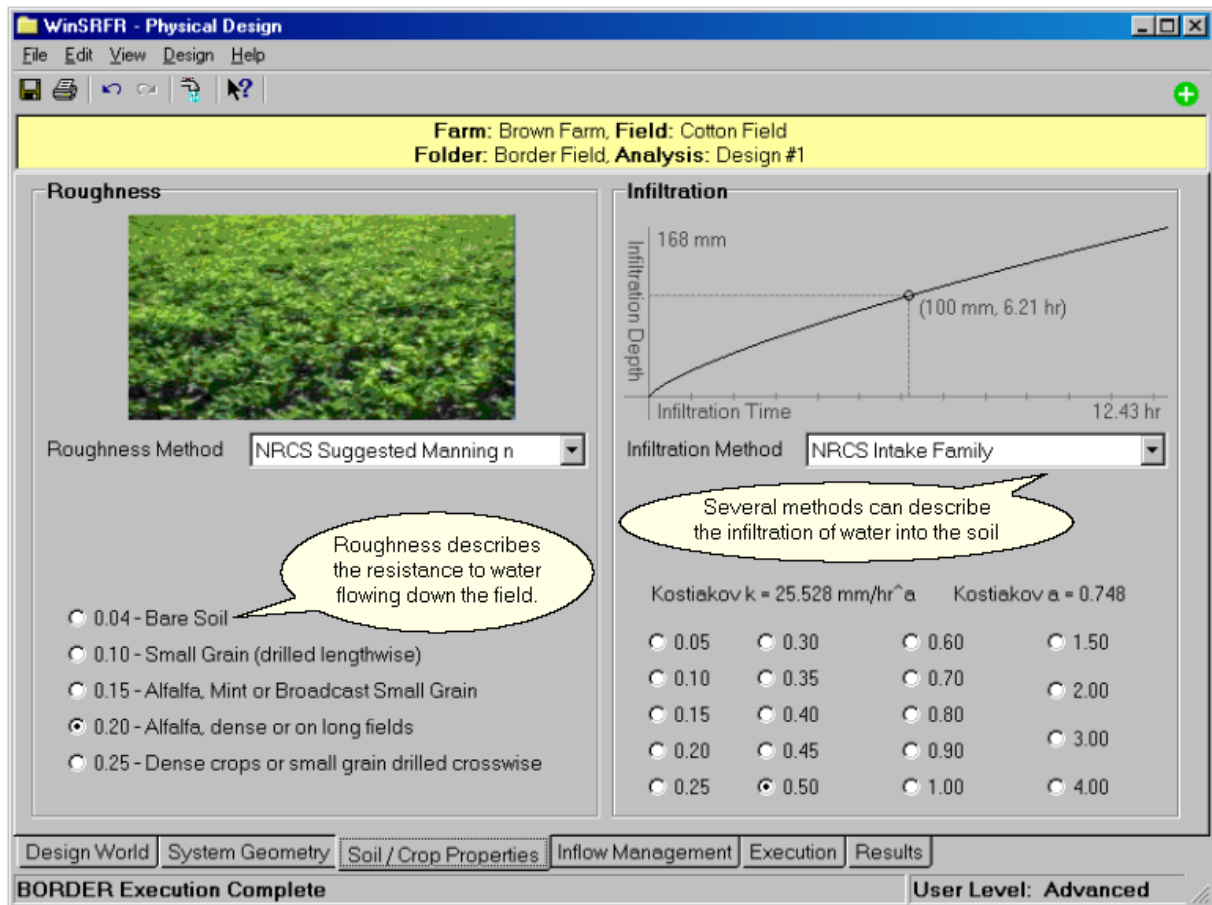
Transfer Trapezoid Data to Simulation

Save Field Data & Close Cancel Help

Figure 1.4.3.1c - Cross-Sectional Data Entered as Profilometer Readings

### 1.4.3.2 Soil / Crop Properties

The Soil / Crop Properties tab describes the field's hydraulic roughness and infiltration characteristics. Inputs that need to be provided and choices for those inputs depend on the particular World.



### Hydraulic Roughness

Defining roughness characteristics involves selecting a roughness calculation method and entering the corresponding roughness parameters. The calculation method is selected using the Roughness Method drop-down list. Two roughness calculation methods are available to all Worlds.

1. User Entered Manning n
2. NRCS Recommended Manning n

Both methods employ the Manning formula to calculate hydraulic resistance, but with the first option the user has to manually enter a Manning n value and with the second option buttons are used to select from a predefined list, consisting of the values recommended by the USDA-NRCS surface irrigation design guides. If locally calibrated Manning n information is available, then option 1 should be used. Selecting that option will produce an input box for Manning n. When using option 2, WinSRFR provides images of field conditions for the recommended n values, as shown in the illustration.

The Simulation World offers two additional hydraulic roughness computational procedures:

3. Manning  $n = C_n * Y^{A_n}$
4. Sayre-Albertson Chi

Both options allow the user to combine the effect of soil hydraulic roughness with vegetation drag and are recommended for advanced users only. A technical description of these options is provided in Appendix XX. Selecting 3 will display the input boxes for the parameters  $C_n$  and  $A_n$  while an input box for Chi will appear when selecting option 4.

It should be noted that among the Event Analysis procedures, only the Two-Point Method uses the Manning  $n$  in its calculations. The Merriam-Keller approach does not require an  $n$  value, but the user needs to provide such an input in order to verify the results via simulation. The Probe Penetration Analysis does not require Manning  $n$  either, and the method does not produce infiltration parameters. Still, the user may choose to enter an  $n$  value, especially if the underlying data are later copied into the Simulation World for further analysis.

### Infiltration Characteristics

Infiltration properties are critical to surface irrigation system behavior and also the input that is most difficult to define for irrigation analysis. An understanding of WinSRFR computational procedures is needed in order to use the infiltration options effectively. WinSRFR computes infiltration using a general expression of the form

$$Z = z(k, a, \dots, t - t_x) * W$$

where upper case  $Z$  is the infiltrated volume per unit length, lower case  $z$  has dimensions volume/length/width and is a function of the empirical infiltration parameters  $k$ ,  $a$ , etc., and  $W$  is a width (length), of time  $t$  and the advance time to a location  $x$ ,  $t_x$ . In the border and basin case,  $W$  is the field width, while for furrows,  $W$  is a nominal wetted perimeter. Hence, when working with borders and basins, users need to select an infiltration formula, i.e. the method for computing  $z$ , and then enter the corresponding parameter values. When simulating furrow irrigation, users also need to be concerned with defining an approach for calculating  $W$ .

WinSRFR offers six infiltration formula choices. A selection is made using the Infiltration Formula drop-down list. Choices are:

1. Known Characteristic Infiltration Time
2. NRCS Infiltration Family
3. Time Rated Intake Family
4. Kostiakov Formula
5. Modified Kostiakov Formula
6. Branch Function

These functions are explained in Appendix XX – WinSRFR infiltration functions. Physical Design and Operational Analysis procedures were developed based on options 1-4 only. Therefore, the last two options are not displayed in those Worlds. All six options are available for simulation, however. In any World, the default infiltration formula is the NRCS Infiltration Family.



After selecting a particular option, WinSRFR will display input boxes for the corresponding input parameters except when the selection is the NRCS Infiltration Family, case in which the program displays option buttons for selecting a specific NRCS family. Of critical importance is that infiltration parameters have to be dimensionally compatible with the calculations indicated in Eq. XX, independently of the unit system selected. For example, if using the Kostiakov formula, WinSRFR expects the parameter  $k$  to have dimensions of Length/Time<sup>a</sup> while the exponent  $a$  is dimensionless. This translates into units of, for example, mm/hr<sup>a</sup> if working in metric units, and in/hr<sup>a</sup> if working in English units.

A value of  $W$  needs to be calculated only for simulation purposes and only when working with furrows. Such a choice is not required for Event Analysis, Design, and Operations. WinSRFR offers five choices for calculating this effect, namely:

1. Local Wetted Perimeter
2. Upstream Wetted Perimeter
3. Wetted Perimeter at Normal Depth
4. Furrow Spacing
5. NRCS Empirical Function

Again, the user is referred to Appendix XX for technical details on these options. By default, the NRCS Empirical Function is selected whenever the selected infiltration formula is the NRCS Infiltration Family. For other infiltration formulas, WinSRFR defaults to the Furrow Spacing option. It is not recommended to use the NRCS empirical Function with any other function other than the NRCS Infiltration Family. When using any other infiltration formula, users must ensure that the parameter values provided were in effect calculated with the selected Wetted Perimeter option. For example, WinSRFR's Event Analysis procedures calculate, first, infiltration parameters needed to compute  $Z$  (volume/length, see Eq. X), and then use the furrow spacing to convert those parameters to their equivalents for computing  $z$  (volume/length/width). If the WinSRFR estimated parameters are used in simulation, the user should not arbitrarily change the Wetted Perimeter option to, say, Upstream Wetted Perimeter, as the resulting  $W$ , when multiplied  $z$ , will not yield the correct value of  $Z$ .

The Simulation World offers still another option for calculating infiltration. The Enable Limiting Depth option is used in cases where infiltration is limited by a hardpan soil layer. In such cases, cumulative infiltration depth will not increase anywhere beyond the user specified value. The input box for the limiting values is enabled whenever the Enable Limiting Depth box is checked. The assumption in using this method is that the user knows what depth of water can infiltrate before the wetting front reaches the hardpan; this is not the depth of the hardpan.

### **Infiltration Formula Matching**

Infiltration formula matching occurs whenever the user changes the infiltration formula using the Infiltration Formula drop-down list. The action that follows depends on the option selected under the User Preferences/Dialogs/ Infiltration Formula. Those options are:

1. No Matching
2. Automatic Matching
3. Confirmed Matching

The No Matching option disables the Match Infiltration Formula mechanism. In this case, the new infiltration formula selection is adopted and the current infiltration parameter values are preserved as



displayed in the Soil and Crop Properties Tab. This can cause large differences in infiltration depth vs. time. Further, if the original infiltration formula has more parameters than the alternative equation, the additional parameters are ignored.

Both the Automatic and Confirmed Matching options enable WinSRFR's infiltration formula matching mechanism. This mechanism maps an infiltration equation into an alternative equation (i.e., fits a known infiltration equation with a specific set of parameters to an alternative equation with a different set of parameters, with the alternative equation approximately matching the behavior of the original equation). Such a conversion is necessary under several different circumstances. For example, the Physical Design and Operational Analysis World procedures were developed using the Kostiakov formula. If the available infiltration information is for an alternative formulation (for example, based on the Branch function), then the user needs to define a Kostiakov formula that will approximate the desired Branch function for at least the time needed to apply the target irrigation depth. In other cases, the user may recognize the uncertainty of the available infiltration information and may want to examine the sensitivity of the analysis to an alternative infiltration formula that predicts the same infiltrated depth for a known opportunity time as the original one, but with a different transient and/or steady-state behavior.

When the Automatic Option is enabled, WinSRFR automatically matches the new infiltration formula selection based on the original selection and parameter values. The user has no control over the output and no means for comparing the shape of the original and fitted function. Enabling the Confirmed Matching option causes WinSRFR to launch the [Match Infiltration Formula Dialog](#) every time an infiltration formula is chosen using the Infiltration Formula drop-down list. From this dialog box, the user can edit the parameters of the alternative infiltration function until obtaining a desired fit to the original function. At the same time that the Dialog is displayed, the Soil and Crop Properties presents plots of the original and alternative infiltration functions, allowing the user to view the effect of parameter value changes. The matching mechanism is based on the concept of characteristic time, i.e., the time needed to infiltrate a desired target depth  $z$  (see Equation xx). The Dialog sets  $z$  equal to the desired average application depth  $D_{req}$ , but a different  $z$  can be specified, if so desired. Once a desired fit is achieved, the user can press the OK button in the Infiltration Function Matching Dialog to transfer the resulting parameters to the Soil and Crop Properties Tab and close the dialog box. Pressing Cancel will abort the operation and restore the original infiltration function and its parameters.

### 1.4.3.3 Inflow Management

The Inflow Management tab is used to enter data related to field inflows and outflows. The tab is named Inflow Management when in the [Physical Design](#), [Operations Analysis](#), and [Simulation Worlds](#) and in those cases, the tab allows the user to enter only inflow information. In the [Event Analysis World](#), both inflows and outflows are inputs to the analysis and therefore the tab is named Inflow / Runoff. The Simulation World offers various options for specifying the field inflow and only subsets of those options are accommodated by other Worlds. Hence, the following discussion is largely based on the more detailed options available in the Simulation World.

**WinSRFR - Event Analysis**

File Edit View Event Help

Farm: Brown Farm, Field: Cotton Field  
Folder: Furrow Irrigation, Analysis: Infiltrated Profile

**Inflow / Runoff per Furrow**

Unit Water Cost: 40.00 \$/ML  
Target Infiltration Depth,  $Z_n$ : 103 mm  
Inflow Rate,  $Q$ : 2 lps  
Inflow Method: Standard Hydrograph

**Cutoff Options**

Method: Time-Based Cutoff  
Cutoff Time,  $T_{co}$ : 6 hr

**Cutback Options**

Method: Time-Based Cutback  
Cutback Time: 0.5 of Cutoff  
Cutback Rate: 0.5 of Inflow Rate

**Runoff Rate**

Time (hr)	Runoff (lps)
5.5	0
5.7	0.3
5.8	0.4
5.9	0.6
6	0.6
6.1	0.6
6.2	0.5
6.3	0.4

**Inflow-Runoff Mass Balance**

Volume Applied: 0.032 ML  
- Runoff: 0.002 ML  
= Infiltrated: 0.031 ML

**Average Infiltrated Depth:**  
110 mm

Event World System Geometry Inflow / Runoff Analysis Execution Results

====> Proceed down these tabs verifying all data is correct for your field. =====> User Level: Advanced

The Inflow Management Tab first provides input boxes for entering the Unit Water Cost (cost of water per unit volume) and the Required Irrigation Depth,  $D_{req}$ . Both of these variables are used primarily for post-irrigation performance assessment, but  $D_{req}$  is sometimes used to specify inflow options, as will be described further below.

There are two basic approaches for entering inflow information, selectable from the Inflow Method drop-down list. The Tabulated Inflow option allows the user to enter a table of time vs. discharge values. Such an approach should be used when the analysis is attempting to reproduce an observed irrigation event based on a measured, time-varying inflow hydrograph. Hence, this option is available in the Event Analysis and Simulation Worlds, but not for Physical Design or Operational Analysis. As with other tabular data, hydrographs can be entered manually, by importing a text file, or from a

spreadsheet using copy/paste. Menus commands available for entering hydrograph data are also similar to those available for other tabular inputs. The tab sheet generates a plot of the hydrograph, as a check on the input data.

**NOTE:** *Because of array size limitations imposed in the original SRFR simulation engine, the tabulated hydrograph is presently limited to 20 rows of data.*

The Standard Hydrograph option allows the user to specify simple inflow hydrographs, for example a constant inflow rate with a prescribed cutoff time, but the selection also enables some relatively advanced input options. Upon selecting Standard Hydrograph, WinSRFR displays an input box for the Inflow Rate  $Q$ , and frame boxes that are used to specify cutoff and/or cutback options. The inflow rate is assumed constant, unless cutback options are specified. Available cutoff options are the following:

1. Time-based cutoff – Cutoff occurs at the user-specified cutoff time  $T_{co}$ , the time elapsed since the start of the irrigation. This is the default selection when using a Standard Hydrograph. Inflow rate may vary, however, depending on cutback options described further below.
2. Distance-based cutoff – Cutoff occurs at a prescribed Cutoff Location  $X_{co}$ , expressed as a function of the field length  $L$  ( $X_{co} = R * L$ ). This location is the position of the advancing stream front.
3. Distance and Infiltration Depth – Cutoff occurs when a given infiltration depth  $z$ , expressed as a fraction of  $D_{req}$  ( $z = R_z * D_{req}$ ) has accumulated at a prescribed downstream Cutoff Location ( $X_{co} = R * L$ ). Note that infiltration will ultimately exceed the given infiltration depth, depending on the time needed for water to recede at the prescribed location.
4. Distance and Opportunity Time - Cutoff occurs when a given infiltration Opportunity Time (total elapsed time minus the advance time) has been experienced at a given downstream Cutoff Location ( $X_{co} = R * L$ ).
5. Upstream Infiltrated Depth - In the case of furrows and basins, cutoff occurs when the infiltrated depth at the head end of the field matches the prescribed infiltration depth, expressed as a function of  $D_{req}$  ( $z = R_z * D_{req}$ ). Ultimate infiltration will exceed the prescribed depth, depending on the lag time between cutoff and initial recession. In the case of graded border strips, WinSRFR attempts to calculate a cutoff time that will ultimately infiltrate the prescribed depth at the head end of the field. The algorithm relies on a dimensionless database of previously run simulations to predict the lag time necessary to achieve this objective.

Cutback options are as follows:

1. No Cutback - This is the default selection for the Standard Hydrograph.
2. Time-Based Cutback – Inflow rate is reduced at the specified Cutback Time and to the Cutback Rate  $Q_{cb}$ , expressed as a function of the initial  $Q$  ( $Q_{cb} = R_Q * Q$ )
3. Distance-Based Cutback - Inflow rate is reduced when the advancing stream reaches the specified Cutback Location to the specified Cutback Rate.

Note that the time-based cutback option depends on cutoff time and, therefore, is undefined when using any distance-based cutoff. Also, many of the cutoff and cutback options described above are not available in either Event Analysis, Physical Design or Operational Analysis.

Outflow data are a required input in the Event Analysis World, but only for systems with an open-end downstream boundary condition. Outflow can be specified only as a tabulated hydrograph. Like the inflow data, data entry is either manual, from a text file, or by using copy/paste.

#### 1.4.3.4 Data Summary

For the [Simulation World](#), a summary of the data from the [System Geometry](#), [Soil / Crop Properties](#) and [Inflow Management](#) tabs is displayed in the Data Summary tab. Notice that there are no graphs and only numeric data can be changed. You must return to the original tabs to make selection changes.

**WinSRFR - Simulation**

File Edit View Simulation Help

Farm: Brown Farm, Field: Cotton Field  
Folder: Folder 1, Simulation: Infiltrated Profile Verification

**System Geometry**

Trapezoid Furrow, No Drainback, Open End

Slope, S 0.0005 m/m

Bottom Width 200 mm

Side Slope 2 H/V

Maximum Depth 200 mm

Furrow Spacing 1.5 m

Furrow Length 185.93 m

**Inflow Management**

Standard Hydrograph

Unit Water Cost 40.00 \$/ML

Target Infiltration Depth, Z<sub>n</sub> 103 mm

Time-Based Cutoff, Time-Based Cutback

Inflow Rate, Q 2 lps

Cutoff Time, T<sub>co</sub> 6 hr

Cutback Time 0.5 of Cutoff

Cutback Rate 0.5 of Inflow Rate

**Infiltration**

NRCS Intake Family (0.50), NRCS Empirical Function

Kostiakov  $k = 25.528 \text{ mm/hr}^a$  Kostiakov  $a = 0.7475$

**Roughness**

NRCS Suggested Manning  $n$

☐ 0.04 ☐ 0.10 ☐ 0.15 ☒ 0.20 ☐ 0.25

Simulation World System Geometry Soil / Crop Properties Inflow Management **Data Summary** Execution Results

====> Proceed down these tabs verifying all data is correct for your field. ====> User Level: Advanced

Remember that What's This? help is available for all the controls. Use the Help / What's This? menu item or its associated toolbar button to access the What's This? help.

### 1.4.3.5 Probe Measurements

When using the Infiltrated Profile Analysis in the Event Analysis World, the Probe Measurements tab is used to enter pre and post irrigation data as shown below. You will enter data in some columns while WinSRFR calculates the data in other columns:

#### Pre-Irrigation Soil Water Depletion Table

You Enter: Profile Depth, Texture, AWC & SWD

WinSRFR Calculates: Cumulative Depth, Profile SWD, Cumulative SWD

#### Post-Irrigation Infiltrated Depths Table

You Enter: Distance, Probe Depth

WinSRFR Calculates: Profile, Root Zone, & Useful Infiltrated Depths and Deep Percolation

WinSRFR - Border - Measured infiltration profile data (probe penetration analysis)

File Edit View Evaluation Help

Farm: Event Analysis Examples, Field: Tests  
Folder: Irrigation Evaluations, Analysis: Infiltrated Profile Analysis

#### Pre-Irrigation Soil Water Depletion - SWD

	Profile Depth (m)	Cum. Depth (m)	Texture	AWC (mm/m)	SWD (%)	Profile SWD (mm)	Cum. SWD (mm)
▶	0.2	0.2	SiL	180	60	22	22
	0.4	0.6	SiCL	170	50	34	56
	0.6	1.2	SiC	160	20	19	75

Root Zone Depth: 1.2 m  
Leaching Fraction: 10 %  
Probe Length: 1.4 m

**Warning** - Leaching Requirement Underestimation

Soil Moisture Deficit: 75 mm  
+ Leaching Requirement: 7 mm  
= Irrigation Target Depth: 82 mm

#### Post-Irrigation Infiltrated Depths - ID

	Distance (m)	Probe Depth (m)	Profile ID (mm)	Root Zone ID (mm)	Useful ID (mm)	Deep Perc. (mm)
▶	0	1.4	75	75	75	NaN
	25	1.4	75	75	75	NaN
	50	1.35	75	75	75	NaN
	75	1.35	75	75	75	NaN
	100	1.25	75	75	75	NaN
	125	1.2	75	75	75	0
	150	1.15	73	73	73	0

Event World System Geometry Soil Crop Properties Inflow / Runoff **Probe Measurements** Execution Results

====> Proceed down these tabs verifying all data is correct for your field. =====> User Level: Standard

### 1.4.3.6 Advance / Recession

When using the Merriam-Keller analysis in the Event Analysis World, the Advance / Recession tab is used to enter the irrigation's advance and recession Distances & Times.

WinSRFR calculates the Opportunity Times as the differences between the Recession and Advance times.

**WinSRFR - Furrow - Measured advance and recession data (Merriam-Keller)**

File Edit View Evaluation Help

Farm: Event Analysis Examples, Field: Tests  
Folder: Irrigation Evaluations, Analysis: Merriam-Keller Analysis

Advance Table			Recession Table			Opportunity Time Table		
	Distance (m)	Time (min)		Distance (m)	Time (min)		Distance (m)	Time (min)
▶	0	0	▶	0	613.5	▶	0	613.5
	25	9		25	624		25	615
	50	17.5		50	629.5		50	612
	75	29		75	631.5		75	602.5
	100	39		100	633		100	594
	125	50.5		125	635.5		125	585
	150	61.5		150	636.5		150	575
	175	73		175	637.5		175	564.5
	200	84		200	640.5		200	556.5
	225	99		225	642.5		225	543.5
	250	117.5		250	644.5		250	527
	275	135		275	646		275	511
	300	159		300	647		300	488
	325	177.5		325	648		325	470.5
	350	194.5		350	649		350	454.5
	...	...		...	...		...	...

Average = 451.1 min

EventWorld System Geometry Soil Crop Properties Inflow / Runoff **Advance / Recession** Execution Results

====> Proceed down these tabs verifying all data is correct for your field. ====> User Level: Standard

### 1.4.3.7 Two-Point Data

When using the Elliot-Walker two-point analysis in the Event Analysis World, the Two-Point Advance tab is used to end the Distances & Times for the two points.

WinSRFR - Furrow - Two-point data (Elliot-Walker)

File Edit View Evaluation Help

Farm: Event Analysis Examples, Field: Tests  
Folder: Irrigation Evaluations, Analysis: Elliot-Walker (Two-Point) Analysis - Trapezoid Furrow

**Two-Point Advance**

	Distance	Time	Elevation Drop	Normal Depth	Inflow Volume	Surface Volume	Infiltrated Volume
Point 1	300 m	2.65 hr	1317 mm	21 mm	0.011 ML	0.001 ML	0.01 ML
Point 2	625 m	8.55 hr	2744 mm	21 mm	0.035 ML	0.002 ML	0.033 ML
Power Advance Exponent	0.627						

Event World System Geometry Soil Crop Properties Inflow / Runoff **Two-Point Advance** Execution Results

====> Proceed down these tabs verifying all data is correct for your field. ====> User Level: Advanced

Several parameters relating to these two points are calculated and displayed to aid in your analysis.

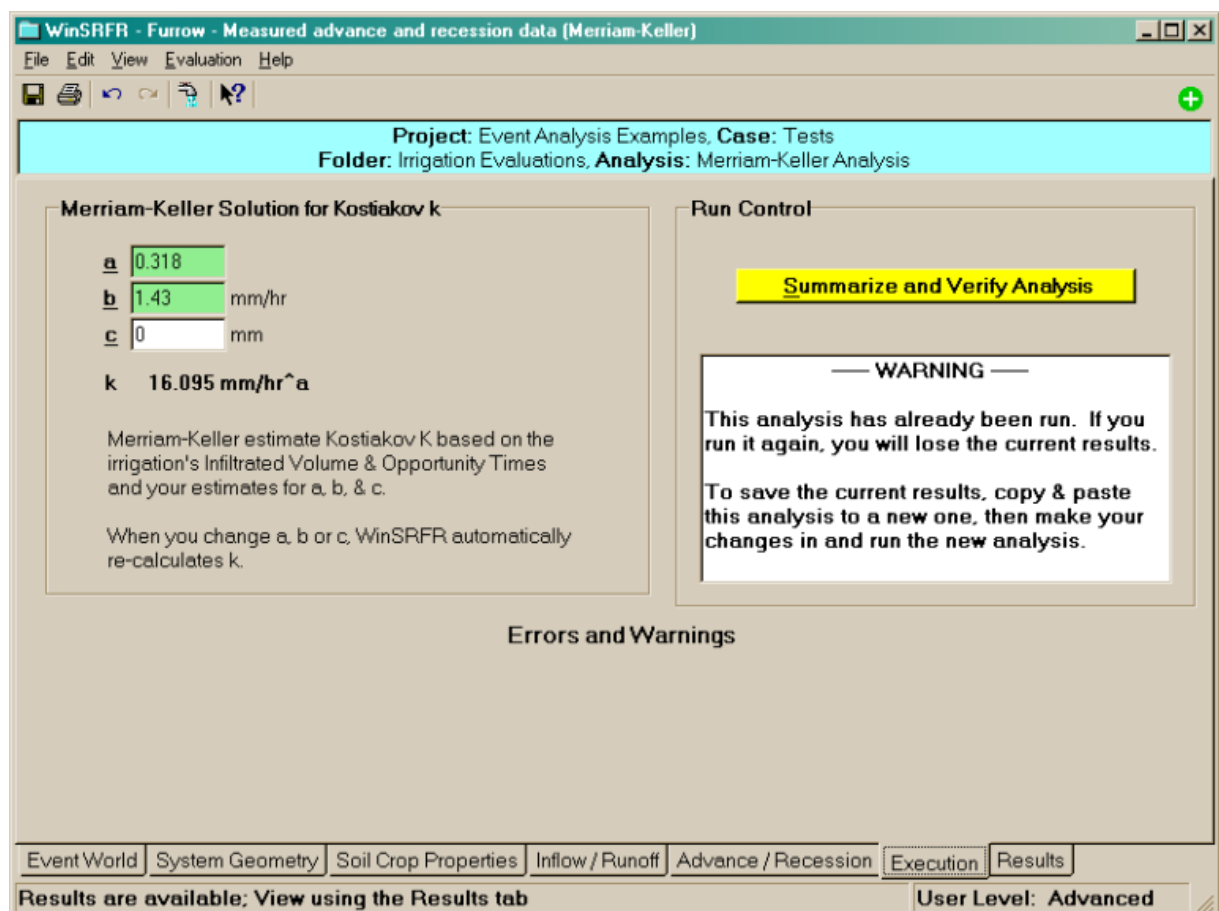
### 1.4.4 Execution Control Tabs

Analyses and output reports are generated from the Execution Tab. Depending on the World, the tab may display requests for additional inputs that need to be provided by the user (e.g., Event Analysis, discussed under [Common Tasks](#)) or program execution options that may or may not need to be modified by the user (Physical Design, Operation Analysis, Simulation, discussed in the following paragraphs). To run an analysis, press the Run (Simulation, Design, Operations) or Summarize Analysis (Event Analysis) button in the Run Control frame box. The Run Control box provides two visual aids to remind the user if results are already available: the Run button turns from green to yellow after running the analysis for the first time and a text message is displayed.

#### 1.4.4.1 Merriam-Keller Infiltration Estimation

When performing a Merriam-Keller analysis In the Event Analysis World, the Execution Tab allows user to enter values for Kostiakov a, b and c. WinSRFR then estimates Kostiakov k based on these values plus previously input Inflow, Runoff, Advance and Recession data.

Pressing the Summarize and Verify Analysis button generates the analysis results that can be viewed using the [Results Tab](#).





#### 1.4.4.2 Elliot-Walker Infiltration Estimation

When performing a Merriam-Keller analysis in the Event Analysis World, the Execution Tab allows users estimate Kostiakov infiltration parameters. Kostiakov  $b$  can be either manually entered or estimated from previously estimated runoff data. WinSRFR then estimates Kostiakov  $a$  &  $k$  based on these values plus previously input Inflow, Runoff, Advance and Recession data.

Pressing the Summarize and Verify Analysis button generates the analysis results that can be viewed using the [Results Tab](#).

WinSRFR - Furrow - Two-point data (Elliot-Walker)

File Edit View Evaluation Help

Project: Event Analysis Examples, Case: Tests  
Folder: Irrigation Evaluations, Analysis: Elliot-Walker (Two-Point) Analysis - Trapezoid Furrow

Elliot-Walker estimates for Kostiakov  $b$ ,  $a$  &  $k$

☐ Manually enter  $b$   
☒ Calculate  $b$  from steady runoff data

$b$  is estimated as:  $(Q_{avg} - Q_{ro}) * 0.5 / Area$

$Q_{avg}$  at  $T_{co}$  1.12 lps  
 $- Q_{ro}$  at  $T_{co}$  0.35 lps  
 $= Q_{avg} - Q_{ro}$  0.76 lps

$b$  1.44 mm/hr

$a$  &  $k$  are calculated from  $b$ , the Two-Point data and the Surface Shape Factor.

0.76

Surface Shape Factor

$a$  0.291  
 $k$  16.91 mm/hr <sup>$a$</sup>

Run Control

— WARNING —

This analysis has already been run. If you run it again, you will lose the current results.

To save the current results, copy & paste this analysis to a new one, then make your changes in and run the new analysis.

Errors and Warnings

Event World System Geometry Soil Crop Properties Inflow / Runoff Two-Point Advance Execution Results

====> Proceed down these tabs verifying all data is correct for your field. ====> User Level: Advanced

### 1.4.4.3 Basin Design

When designing a level-basin using the [Physical Design World](#), the Execution Tab presents a table-like form that can be used to modify key variable inputs and analytical options. In a sense, this tab presents a quick summary of the design options available for level basins, showing for each case which variables need to be entered and which are program outputs. The user can select an alternative analysis with the option buttons at the top of the table and then enter the needed variable inputs using the input boxes at the right. Each column in the table represents a design option; these options are also selectable using the Design World Tab. After selecting an option, the column is highlighted using white for values the user must enter and blue for values that WinSRFR will calculate. The current values are displayed to the right of the table with default values displayed using the background color; these values must be verified to ensure they are correct for the design being run. User entered values have a green background while calculated values have a blue background. If values still need to be calculated, they will display as 'TBD' (to be determined).

Pressing the Run button generates the design results that can be viewed using the [Results Tab](#).

**WinSRFR - Basin Design - Find the maximum limits for a field's dimensions.**

File Edit View Design Help

Project: Basin Examples, Case: Basin Field  
Folder: Example Basin Design, Analysis: Step 1: Upper limit for length

**BASIN Design**

AVAILABLE OPTIONS  
Select One

	General Design		Maximum Limit			Advance Distance			
<b>Dreq</b>	Enter	Enter	Enter	Enter	Enter	Enter	Enter	Enter	100 mm
<b>L</b>	Enter		Enter			Enter			229.4 m
<b>W</b>		Enter			Enter			Enter	62.68 m
<b>Q</b>	Enter	Enter	Enter	Enter		Enter	Enter		230 lps
<b>DU</b>	Enter	Enter	Enter		Enter		Enter		0.8
<b>Tco</b>									130.3 min
<b>R</b>						Enter	Enter	Enter	0.842 of Length

Refer to the Design World tab for more information on the selected option.

**Run Control**

**Run**

**WARNING**

This analysis has already been run. If you run it again, you will lose the current results.

If you want to save the current results, use the Project Management Window to copy & paste this analysis to a new one, then make your changes in and run the newly created analysis.

Design World System Geometry Soil / Crop Properties Inflow Management **Execution** Results

====> Proceed down these tabs verifying all data is correct for your field. ====> User Level: Advanced

#### 1.4.4.4 Border Design

When designing a sloping-border field using the [Physical Design World](#), the Execution Tab displays a summary of key design inputs using editable input boxes (Design Parameters), and also program execution controls. These controls are Border Options, Contour Overlays and Contour Ranges. Border Options control the density of the underlying grid of solutions that are used to generate the border design contours, as well as the contour intervals. With Contour Overlays, the user can select two or more contours to superimpose on output. Contour Ranges are used to control the range of values used to generate the contours. Hence, to expand the range of, say lengths and widths to include in the design contours, enter the desired values in the appropriate input boxes.

The design options can also be selected using the [Design World Tab](#). Default values are displayed using the background color; these values must be verified to ensure they are correct for the design being run. User entered values have a green background while calculated values have a blue background. If the values still need to be calculated, they will be displayed as 'TBD' (to be determined).

Pressing the Run button generates the design results that can be viewed using the [Results Tab](#).

**WinSRFR - Border Design - Given an Inflow Rate, find the tradeoffs between Border Length and Width.**

File Edit View Design Help

Project: Border Examples, Case: Border Field  
Folder: Example Border Design, Analysis: Step 1 - Find optimal length & width

**BORDER Design**

**Design Parameters**

☐ Border Width, W 40 m

☒ Inflow Rate, Q 230 lps

Required Depth, Dreq 100 mm

Depth Criteria Low Quarter

**Contour Ranges**

Border Width 10 to 300 m

Border Length 50 to 600 m

This tab reflects the choices made on the Design World tab.

**Run Control**

**Run**

**WARNING**

This analysis has already been run. If you run it again, you will lose the current results.

If you want to save the current results, use the Project Management Window to copy & paste this analysis to a new one, then make your changes in and run the newly created analysis.

Design World System Geometry Soil / Crop Properties Inflow Management Execution Results

-----> Proceed down these tabs verifying all data is correct for your field. -----> User Level: Advanced

#### 1.4.4.5 Basin Operations

When analyzing the operations of a level-basin using the [Operations Analysis World](#), the Execution Tab presents a table-like form that can be used to modify key variable inputs and analytical options. In a sense, this tab presents a quick summary of the design options available for level basins, showing for each case which variables need to be entered and which are program outputs. The user can select an alternative analysis with the option buttons at the top of the table and then enter the needed variable inputs using the input boxes at the right. Each column in the table represents a design option; these options are also selectable using the Design World Tab. After selecting an option, the column is highlighted using white for values the user must enter and blue for values that WinSRFR will calculate. The current values are displayed to the right of the table with default values displayed using the background color; these values must be verified to ensure they are correct for the design being run. User entered values have a green background while calculated values have a blue background. If values still need to be calculated, they will display as 'TBD' (to be determined).

Pressing the Run button generates the analysis results that can be viewed using the [Results Tab](#).

**Project:** Basin Examples, **Case:** Basin Field  
**Folder:** Example Basin Operations, **Analysis:** Step 3: DU and irrigation guidelines for alfalfa

**BASIN Operations**

AVAILABLE OPTIONS  
 Select One

	General Operation		Max Lim	Adv Dist	Operation Eval		
<u>D</u> req	Enter	Enter	Enter	Enter			100 mm
<u>L</u>	Enter	Enter	Enter	Enter	Enter	Enter	200 m
<u>W</u>	Enter	Enter	Enter	Enter	Enter	Enter	75 m
<u>Q</u>	Enter				Enter	Enter	230 lps
<u>D</u> <u>U</u>		Enter					0.811
<u>T</u> co						Enter	134 min
<u>R</u>				Enter	Enter		0.881 of Length

Refer to the Operations World tab for more information on the selected option.

**Run Control**

**Run**

**WARNING**

This analysis has already been run. If you run it again, you will lose the current results.

If you want to save the current results, use the Project Management Window to copy & paste this analysis to a new one, then make your changes in and run the newly created analysis.

Operations World | System Geometry | Soil / Crop Properties | Inflow Management | **Execution** | Results

====> Proceed down these tabs verifying all data is correct for your field. <====

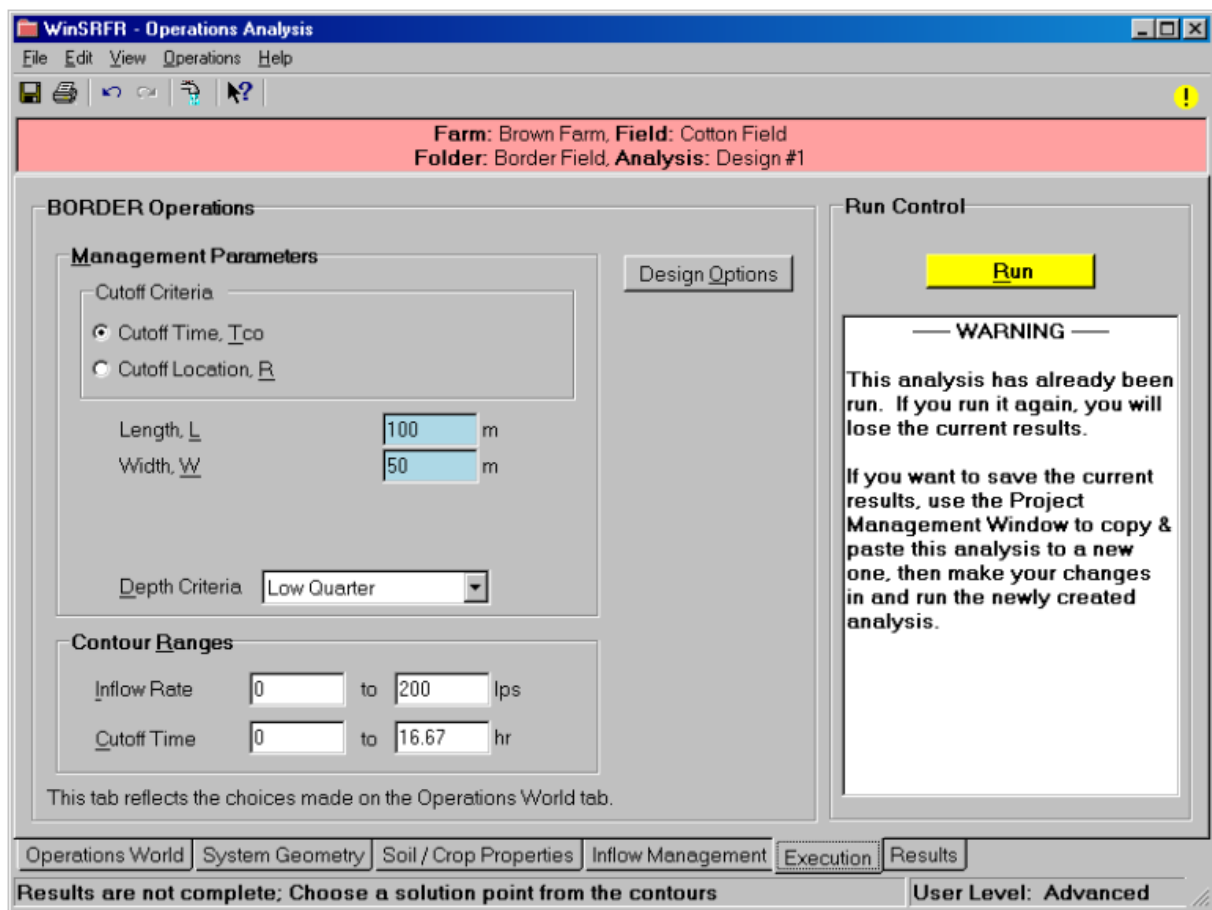
User Level: Advanced

#### 1.4.4.6 Border Operations

When analyzing the operations a sloping-border field using the [Operations Analysis World](#), the Execution Tab displays a summary of key design inputs using editable input boxes (Management Parameters), and also program execution controls. These controls are Design Options and Contour Ranges. Contour Ranges are used to control the range of values used to generate the contours.

The options can also be selected using the [Operations World Tab](#). Default values are displayed using the background color; these values must be verified to ensure they are correct for the analysis being run. User entered values have a green background while calculated values have a blue background. If the values still need to be calculated, they will be displayed as 'TBD' (to be determined).

Pressing the Run button generates the analysis results that can be viewed using the [Results Tab](#).

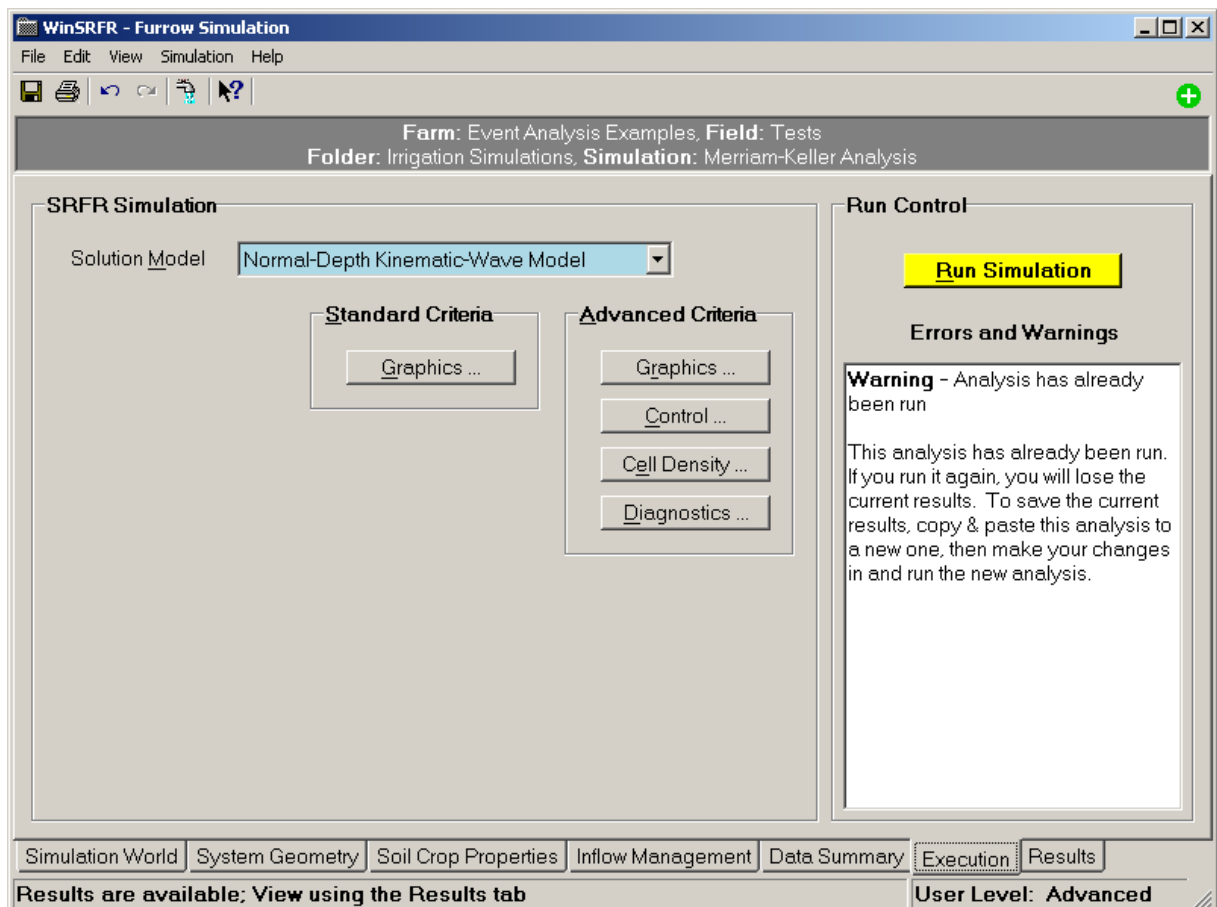


#### 1.4.4.7 Irrigation Simulation

For the [Simulation World](#), the Execution Tab presents three groups of program execution options. The first is the simulation method: zero-inertia or kinematic wave. This option can be modified when the Advanced or Programmer User Level options are selected, but not with the Standard User Level. In that case, the simulation engine will automatically select a simulation approach appropriate to the given hydraulic conditions, as described in section XX.

The second group of options is used to determine the longitudinal field locations at which WinSRFR will plot output hydrographs (water depth and discharge) and also the simulation times at which the program will plot water surface profiles. They are modified by pressing the Graphics button, in Standard Criteria. The resulting Dialog box, Simulation Graphics, displays two grid controls for entering tabular data. The Profile Time Table is for used for entering times at which profiles will be plotted. The user can select to plot these data as depths or water surface elevations. With the Hydrograph Location Table, the user indicates the longitudinal field distances at which hydrograph plots are desired. Similar to other tabular data, these tables can be edited manually, text files can be imported, or spreadsheet data can be transferred using copy/paste. These graphical options are available for all User Levels.

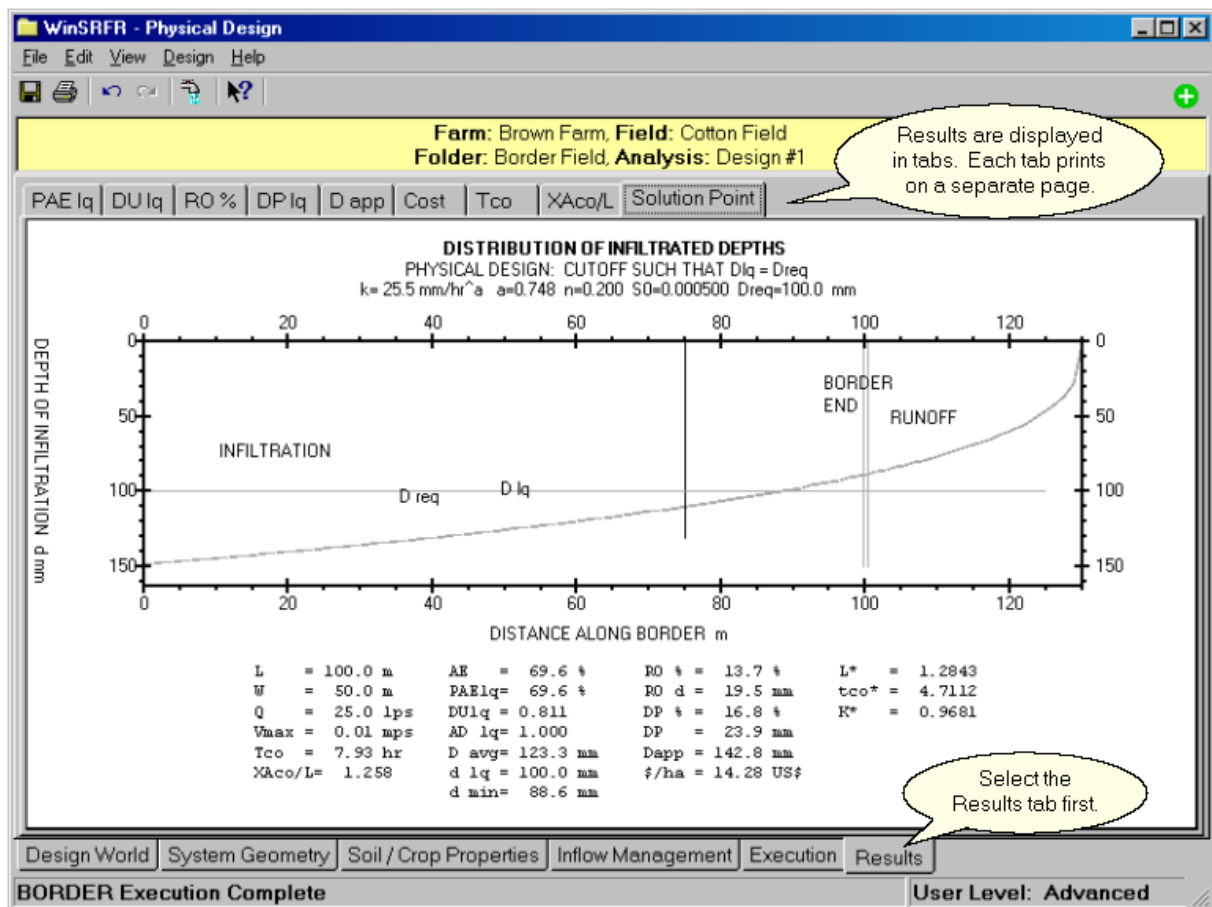
The third group of options, available to Advanced and Programmer Users, consist of additional graphical controls (Graphics), computational solution parameters (Controls), computational grid controls (Cell Density), and Diagnostic controls (Diagnostics). Options under Graphics affect the scaling of the Animation Window, i.e., the window that illustrates the surface and subsurface flow of water as a function of time and distance. These controls allow zooming in on some portion of the simulated stream. Computational controls under the Controls button rarely need to be modified. They are described in appendix XX. Although WinSRFR automatically calculates and adjusts the solution grid for each particular situation, there are cases where the user may need to make manual adjustments using the Cell Density controls to avoid anomalous behavior of the simulation, for example when the analysis is based on variable field properties (variable field elevations, cross section, etc.) and inflow. Cell Density is used to modify the number of spatial increments used in the numerical solution.



### 1.4.5 Run Results Tabs

After successfully completing an analysis, WinSRFR will display the corresponding results in a series of tabs located at the top of the window. These tabs are only visible after the Results Tab at the bottom of the window is selected. Each results tab contains data that will print on a separate page.

The tabs are accessible from its World Window, and are located at the top of the form. Results tabs display either text alone or a combination of text and graphs, with each tab representing a separate print page. Use the View menu to select the format for viewing & printing the results. Results will be displayed in the Results Tabs as long as the associated inputs do not change. If the , the results will be incompatible with the current input values and WinSRFR will alert the user with a message in the Results Tab. If accidental changes are made to the inputs, or if changes are made but then you decide to keep the original inputs and results, you can undo the input changes using the Edit/Undo commands. The output Result Tabs will display again when all original inputs are restored using the Undo commands.



All graphs in the results tab can be copied to the clipboard as either a bitmap or data for pasting into application such as Excel or Word. Use either the right-click context menu or the Edit menu to access the Copy functions.



## 1.4.6 Tools

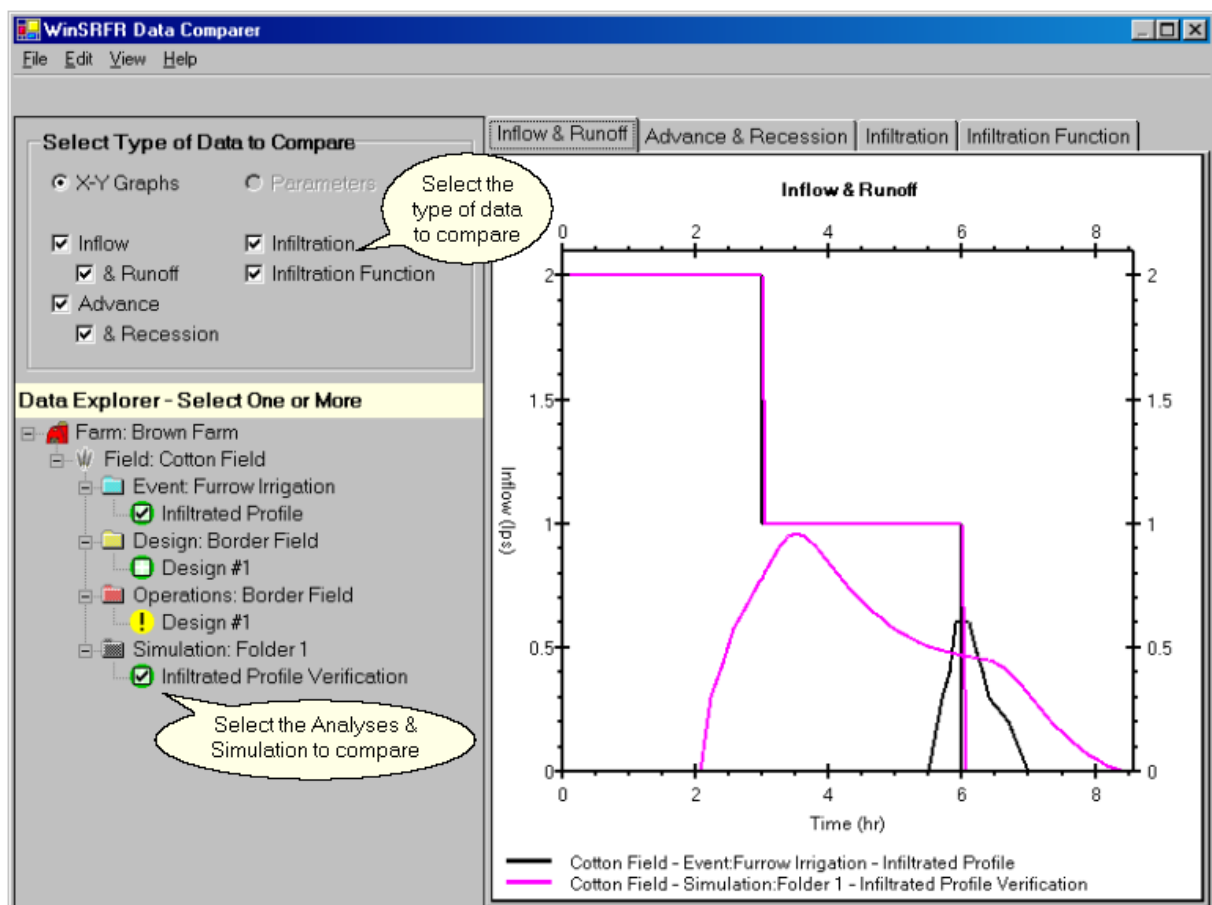
Additional Tools provided by WinSRFR can be found under the Tools menu on the [Project Management Window](#):

- [Data Comparison Tool](#)
- [Conversion Chart Tool](#)

### 1.4.6.1 Data Comparison Tool

The Data Comparison Tool is used to combine and compare graphical results from the Event Analysis and Simulation Worlds. To activate the tool, from the Project Management Window click on the Tools / Data Comparison command. Use the check boxes in the Data Explorer tool to select the analyses that you want to include in the combined chart then press option buttons in the Type of Data to Compare box to select the type of graphical outputs that you want to generate (e.g., advance/recession). Last, use the tabs at the top of the chart window to select the particular chart that you want to view. If you need to change the sequence of colors used to display the different series, use the User Preferences / Color command (you will need to exit the Data Comparison Tool and return to the Project Management Window). You can send the output to a color printer and copy and paste the displayed information to other Windows applications, either as bitmaps or as tabular data.

To clear selections, uncheck the corresponding boxes in the Data Explorer tool. You can also click on the Data Comparison menu command Edit/Clear all Selections to simultaneously unselect all analyses.





### 1.4.6.2 Conversion Chart Tool

From the Project Management Window, click on the Tools / Conversion Chart command to access WinSRFR's Unit Conversion tool. You can use the tool for converting lengths, areas, volumes, and discharges from one unit system to another. Each tabbed form displays a variable in five common unit systems. Enter the known value in the corresponding box and then press Enter.

The Conversion Chart Tool lets you convert English values to Metric and vice versa. It also provides a conversion chart for data types commonly used in WinSRFR:

- Length
- Area
- Depth
- Volume
- Flow Rate

**WinSRFR Conversion Chart**

**FLOW RATE**

English		Metric		
1 gpm =	1 cfs =	1 lpm =	1 lps =	1 cms =
3.79 lpm	1699.0 lpm	0.26 gpm	15.85 gpm	15850 gpm
0.06 lps	28.32 lps	0.00 cfs	0.04 cfs	35.31 cfs
0.000 cms	0.028 cms			

Conversion chart for basic data types

Conversion calculator for specific values

Gal / Min	Cu. Ft / Sec	Liter / Min	Liter / Sec	Cu. M / Sec
448.83	1.00	1699.0	28.32	0.028

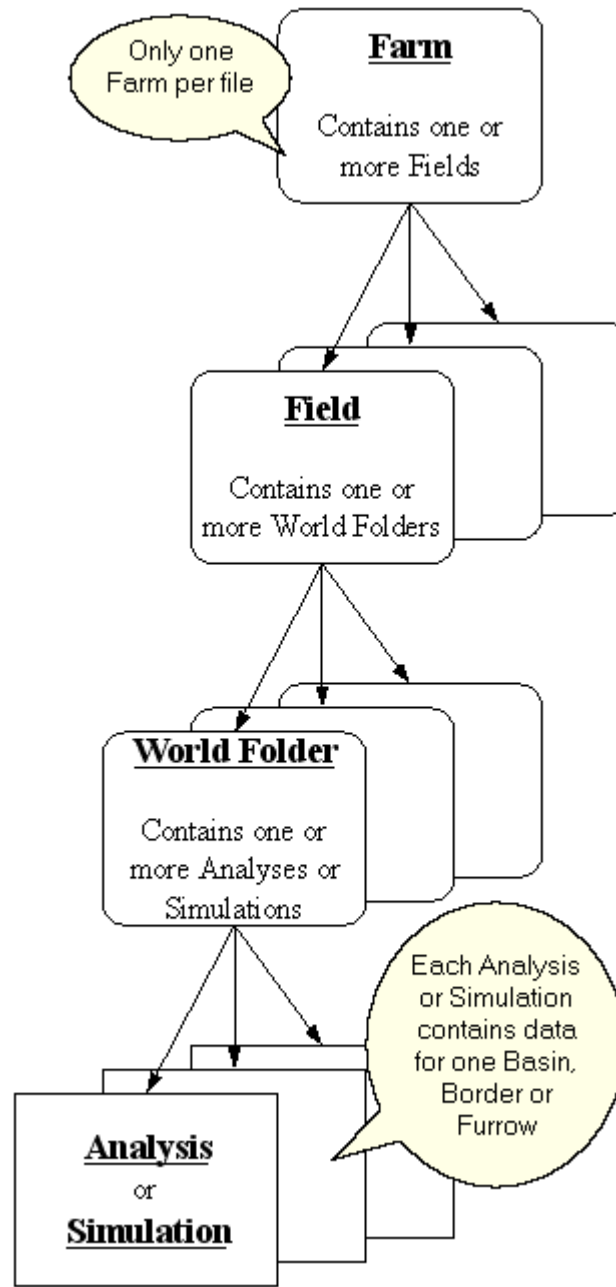
Length Area Depth Volume Flow Rate

Ok Help

To convert a value from English to Metric, select the appropriate tab then enter the value and press Enter. The equivalent value will be displayed in the other fields on that tab. Do the same for Metric to English.

## 1.5 Data Organization and File Management

WinSRFR data is organized in memory and in a file using a hierarchical structure similar to your PC's file system. The top level of this hierarchy is a Farm (Project). This Farm is similar to a folder in that it holds one or more Fields. Fields, in turn, hold one or more World Folders. A WinSRFR file (filename.srfr) contains the complete set of data for one and only one Farm. The nomenclature Farm / field or Project / Case is user selectable in the User Preferences dialog box.



World Folders store the Analyses and Simulations which contain the actual data that WinSRFR operates on. World Folders limit the type of data they store to one WinSRFR World. For example, an Event Folder holds one or more Event Analyses. It cannot hold Design Analyses, Operations Analyses or Simulations. The same is true for all four World Folder types:

<b><u>World Folder type</u></b>	<b><u>Holds</u></b>
Event Folder	Event Analyses
Design Folder	Design Analyses
Operations Folder	Operations Analyses
Simulation Folder	Simulations

See the [Project Management Window](#) and the [Analysis Explorer](#) for User Interface information related to creating and using these data elements.

### 1.5.1 Farm, Field & World Folders

WinSRFR uses a hierarchical storage mechanism to manage its data in memory and also to store the data in a file.

#### **WinSRFR File (filename.srfr)**

A file contains one Farm (Project). If you are working with more than one farm, each farm's data needs to be stored in its own file.

#### **Farm (Project)**

A Farm contains one or more Fields enabling you to group your data by field since each field may have a different geometry, infiltration characteristics, roughness, etc.

#### **Field (Case)**

A Field contains one or more World Folders. As the name implies, a Field enables you to group your data by field (or group fields with similar geometrical, infiltration, and roughness properties). A Field is a collection of World Folders, representing the different types of WinSRFR analyses applied to that field. For example, you may have one Event Folder named "1st Irrigation" and a second Event Folder for the same Field named "2nd Irrigation". The same Field can contain a Design Folder named "Basin Designs" and another for "Border Designs". Any type of analysis can be applied to a Field and any field folder can have as many World Folders as needed, limited only by computer memory.

#### **World Folder**

A World Folder is a collection of related [Analyses or Simulations](#) that contain the actual data that WinSRFR operates on. World Folders limit the type of data they store to their specific world type.. For example, an Event Folder holds one or more Event Analyses, but it cannot hold Physical Design, Operations Analyses, or Simulations, even though the basic data are alike.

You may want to run several analyses on a data set varying only one or a few parameters. If you want to save the results of each run, you should create a new Analysis or Simulation for each run. Analyses

and Simulations can be duplicated using Copy & Paste. Using the [Analysis Explorer](#), simply right-click on the Analysis or Simulation and select Cut or Copy to send it to the clipboard. Then right-click on the World Folder you want to Paste it into.

## 1.5.2 Analyses & Simulations

Analysis and Simulations are the fundamental data objects that WinSRFR works with. They contain:

### Field Data

The field's physical characteristics such as geometry, infiltration and roughness and a description of how the irrigation water is applied to the field. This includes:

[System Geometry](#) data - the physical description of the field's layout

[Soil / Crop Properties](#) data - the field's infiltration and surface roughness characteristics

[Inflow Management](#) data - the description of the flow of irrigation water onto and out of the field

### Run Criteria

The Run Criteria, functions and options used to run the Analysis or Simulation

### Run Results

[Run Results](#) data - the results produced by running the Analysis or Simulation

Because input data are defined at the level of Analyses and Simulations, each of these objects contains its own set of inputs, even though all analyses within a World Folder apply, in principle, to the same field. Changing an input to an Analysis/Simulation within a World Folder (for example, length) does not automatically change the value for that input for other Analyses/Simulations in that World Folder. Analyses/Simulations within a World Folder typically represent analytical scenarios for the given field. For example, a sensitivity analysis for infiltration can be developed within a Simulation World Folder by defining several scenarios, all with the same inputs except the infiltration properties. Copies of the original Analyses/Simulations Object can be created using Copy & Paste, as explained later.

Double-clicking an Analysis or Simulation in the [Analysis Explorer](#) will display its data in the appropriate WinSRFR World. The field data and run criteria are always available for viewing. Run results, however, are only available after you execute a Run.

Results are always available for viewing unless changes are made to the field data or run options. Such changes make the output data inconsistent with the inputs. To view the new results, the simulation must be run again. If both the new and old results need to be saved, then the new scenario needs to be run from a copy of the old scenario. Changes to the input data can be undone by using the Edit/Undo XXXX command, where XXXX represents the input that can be undone. This will restore the original inputs and results.

### 1.5.3 File Management and Management of file Size

WinSRFR uses conventional file management commands to interact with files (New, Open, Close, Save, Save As). Upon opening, the program displays a list of recently opened files, enabling the user to quickly retrieve a recent project. When using the Open command, WinSRFR automatically resets the default directory data file path to the location of the mostly recently opened file (this does not happen if opening a file from the Recent Projects File list). While operating on a file, WinSRFR generates a diagnostic file. By default, the installation program locates this file in a subdirectory of the installation folder. The user can use the User Options to change the location of this diagnostic file.

**NOTE:** *Because WinSRFR files store all pertinent input data and extensive tables of results, those files can grow to several megabytes in size. The user can choose to save only the inputs, and rerun the analysis only when needed to review the output data. Use the File/Clear All Results command to delete all results data.*

## 1.6 User Interface

WinSRFR uses visual elements and Windows services to assist the user in his/her interaction with the program and the data:

**Forms and Dialog Boxes** help the user navigate through the program's main analytical functions and to function-specific options

**Color** is used to distinguish the different worlds and to provide data status.

**Context Menus** provide alternate access to functions for selected items.

**Cut, Copy & Paste** are used to create new Analyses & Simulations from existing ones.

**Help** is available online and in PDF form. Both formats present the same content.

WinSRFR uses two main forms, the [Project Management Window](#) and [World Windows](#). The Project Management Window provides access to a project's folders/objects. A World Window provides access to a particular Analysis/Simulation Object and its data. Currently, WinSRFR allows a single World Window to open for each World. [Dialog Boxes](#) are called by either the Project Management or a World Window, and allow the user to specify user interface and analytical options.

### 1.6.1 User Level

The User Level preference determines whether users can make changes to advanced program execution options offered by the SRFR engine. For most analyses, users do not need to change these execution options from their default values and, furthermore, changes should only be made by users knowledgeable of the program's computational procedures. This choice does not affect program options available in the Physical Design, Operational Analysis, and Event Analysis Worlds.

Three User Levels are provided by WinSRFR:

#### **Standard**

The Standard User Level provides functionality that should be sufficient to most WinSRFR users. This option disables the access to the advanced program execution options.

#### **Advanced**

The Advanced User Level enables access to the advanced program execution options.

#### **Programmer**

The Programmer User Level is reserved for ALARC personnel to aid in testing and debugging WinSRFR. It allows access to options that can disable a simulation in ways difficult to debug

### 1.6.2 User Preferences

User Preferences allow user-customized aspects and defaults for WinSRFR's User Interface and function execution. These preferences vary from user to user on the same PC as they are stored in the Current User section of the Window's Registry.

User Preferences are grouped depending on their use and application:

- Startup - Default values for application-wide data
- Files - Paths to commonly used files / folders
- Views - Options for enabling / disabling and controlling WinSRFR views
- Dialogs - Options controlling whether or not certain dialog boxes are displayed
- Units - Units system and default units selection
- Colors - Colors to use for graphs

See [User Preferences Dialog Box](#) for more details.

## Startup

The Edit/User Preferences/Startup command sets default values in new projects. These include the nomenclature used (Project/Case or Farm/Field), Farm Name, Owner, and Default Evaluator. The last three fields can be left blank.

## Files

The Edit/User Preferences/Startup command sets the path and filename for the WinSRFR diagnostic files. By default, the pathname is set to the folder provided by Windows for application data:

C:\Documents and Settings\jschlegel.ALARC\Application Data\USDA\WinSRFR\1.0

The user can change this field to any path that can be more easily accessed than the default value.

## Views

The Edit/User Preferences/Views command determines whether graphical outputs will be displayed on screen as charts only or in print preview mode, with additional text included. It is also used to control the display of the simulation animation window.

## Dialogs

The Edit/User Preferences/Views command controls the display of two dialogs. If the Suggested Default Values/Unconditionally Accept option is enabled, then WinSRFR will accept recommended SRFR Simulation control changes without prompting the user. If Suggested Default Values/Require Confirmation is enabled instead, then the user will have to verify the recommended changes before they are made. These dialogs inform the user of automated changes in the computational approach.

The Infiltration Formula options control how infiltration parameters will be processed when changing the infiltration formula in the World Window/Soil and Crops Properties tab. The assumption is that in some cases the user will want to keep the existing values but in others will want to keep the shape of the function, independent of the parameter values. The No Matching option simply keeps the existing parameter values. Both the Auto Matching and Confirmed Matching fit the parameters to match the shape of the previously defined infiltration function. Auto Matching does this automatically, while Confirmed Matching displays a dialog box with a chart of the currently defined function and the alternative function, and controls that can be used to manipulate the shape of the alternative function. See Section 4.2.3.4 for more details.

## Units

The Edit/User Preferences/Units command determines whether English or metric units are used by default in both input and output forms. The specific default units for a given variable have been selected based on units typically used in practice. For example, if working in English units, field lengths are typically measured in ft and depths are measured in inches.

**NOTE :** For a session, the user can choose the units of individual input boxes (for example, change from gpm to lps). Unit labels appear to the right of variable input boxes. Units are changed by right-clicking on the label and selecting an alternative unit measure from the resulting drop-down list.

## Colors

The Edit/User Preferences/Units command controls the sequence of colors used to plot multiple time series in the Data Comparison Dialog.

### 1.6.3 Data Exchange with other WinSRFR Projects

To exchange data between WinSRFR data files, run two instances of the WinSRFR program and open the two files of interest. Use the [cut/copy/paste](#) commands to copy and paste entire Field or World Folders or individual Analysis/Simulation Objects.

### 1.6.4 Data Exchange with Windows Applications

Copy/paste commands can be used to copy tabular data from a spreadsheet to WinSRFR, or from WinSRFR to spreadsheets/word processing software. You can also copy WinSRFR graphical outputs to Windows applications that accept bitmaps. When copying tabular data to WinSRFR, the number of columns in the source data needs to match the number of columns in the receiver form (for example, if copying field elevation data, the receiver form expects two columns of data, consisting of longitudinal distance and vertical elevation pairs). When copying spreadsheet data to WinSRFR, you can label the first row in the data with unit labels. If WinSRFR recognizes the unit labels, it will make the necessary unit conversions. WinSRFR recognizes the following unit labels:

<u>Variable</u>	<u>Unit Labels</u>
Length	"m", "ft"
Depth	"mm", "cm", "in"
Side Slope	"H/V"
Slope	"m/m", "m/100m", "ft/ft", "ft/100ft"
Time	"sec", "min", "hr", _
Flow Rate	"cms", "lps", "lpm", "cfs", "gpm"
Percentage	"%"
Soil Water Holding Capacity	"mm/m", "in/ft"



## 1.6.5 Visual Elements

Beyond the usual Windows elements, WinSRFR provides an overall look and feel to its User Interface to help you understand the current state of your Analysis or Simulation.

[Color](#) is used to distinguish the different worlds and to provide data status.

[Context Menus](#) provide alternate access to functions for selected items.

[Help](#) is available online and in PDF form. Both formats present the same content.

[Data Table Entry](#) describes how to manually enter or paste data into data tables.

[Cut / Copy / Paste](#) describes how to create new Analyses or Simulates from current ones.

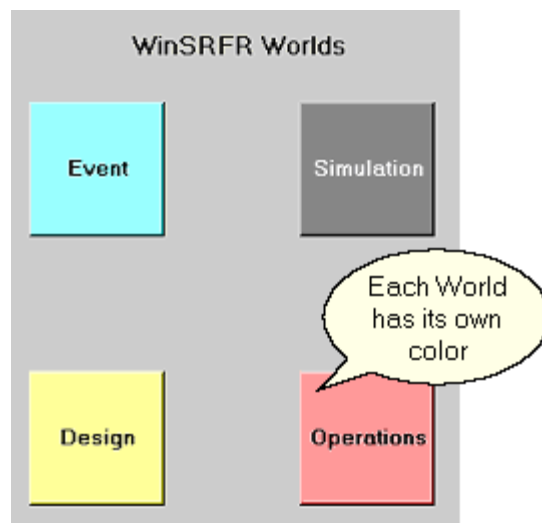
### 1.6.5.1 Color

Color is used by WinSRFR to provide both context and meaning to the data being displayed. Color provides context by distinguishing which World you are working in and gives additional meaning to data indicating its source or state.

#### Color of WinSRFR's Worlds

The Worlds supported by WinSRFR are distinguished by each having its own color.

Event Analysis World:	Blue
Physical Design World:	Yellow
Operations Analysis World:	Red
Simulation world:	Gray

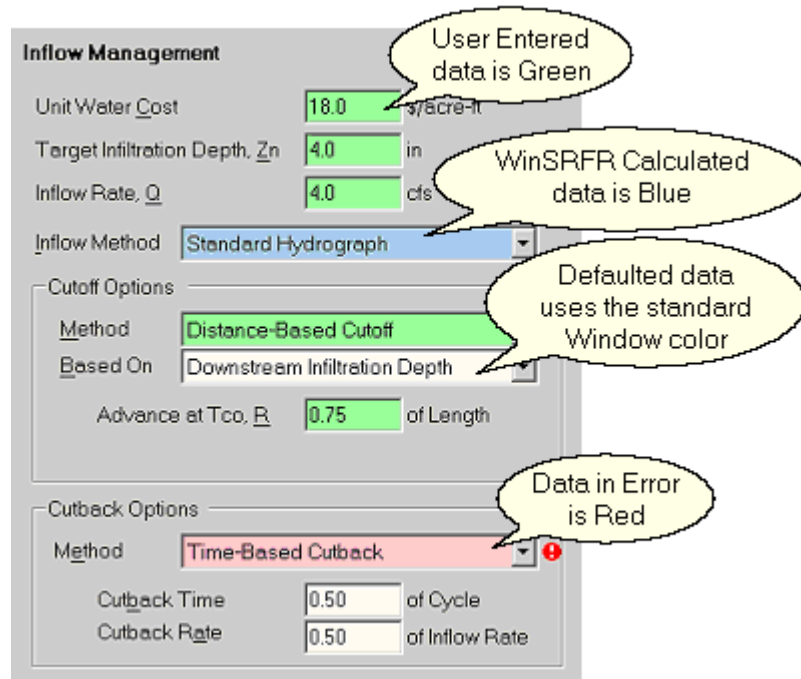


## Color of Data

WinSRFR data can be:

- Defaulted
- User Entered
- WinSRFR Calculated
- In Error

Data fields are highlighted with different colors depending on the source or state of the data value.



**User Entered Data**, whether selection or numeric, is displayed in green.

**WinSRFR Calculated or Limited Data** is displayed in blue. This includes numeric values that have been calculated or are to be calculated by WinSRFR and selection fields that WinSRFR has limited to only one choice.

All data within WinSRFR begins with **Default Data** values that are displayed using the standard Window color. You should always verify that the default data values are correct for your work.

**Selections or Data Values In Error** are displayed in red with an adjacent red icon. Hover the mouse over the icon to display a tooltip describing the error.

### 1.6.5.2 Context Menus

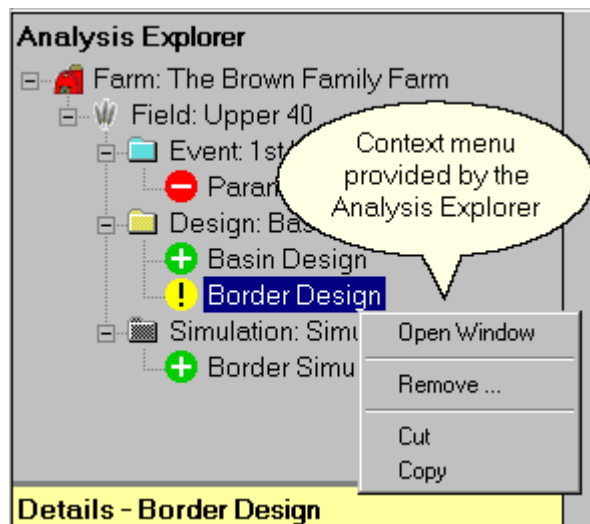
Context menus are primarily used extensively by WinSRFR:

- 1) By the tree view in the [Analysis Explorer](#).
- 2) By the various graphs in the [World Data Tabs](#) and [Run Results](#).
- 3) For [Data Table entry](#).

#### Analysis Explorer Context Menus

The Context Menus in the Analysis Explorer can be accessed by either:

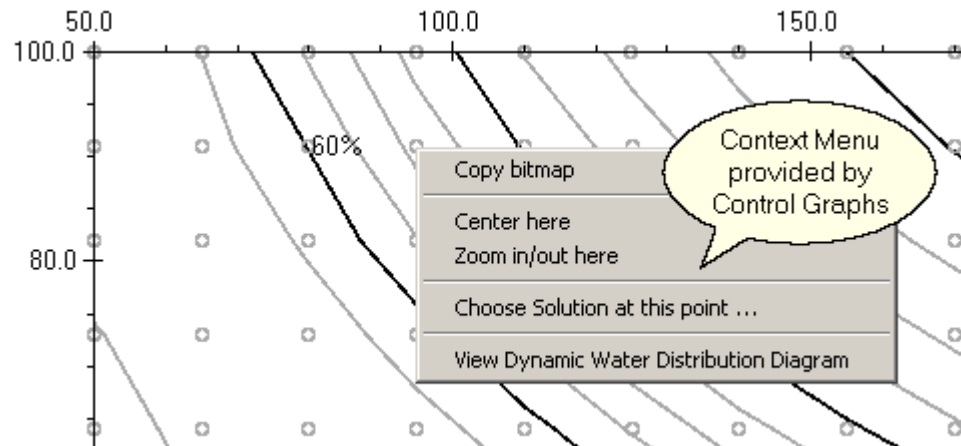
- a) Clicking the right-mouse button on an item in the tree view. Clicking the left-mouse button outside the Context Menu removes it.
- b) Pressing the space bar after selecting an item using the arrow keys. Pressing the escape (Esc) key removes the Context Menu.



The menu displayed is specific to the item selected in the tree view.

## Graphic Context Menus

The Context Menus provided by the various graphs can only be accessed by clicking the right-mouse on the graph. The main menu can be used to access all the functions provided in these Context Menus.



The menu displayed is specific to the graph.

### 1.6.5.3 Help

WinSRFR provides help through many mechanisms, most of which are standard in Windows applications:

#### F1 Key

Pressing the F1 key at any time will display the section in the online help most appropriate to the window that has focus.

#### What's This? Help

What's This? help is accessed under the Help menu or via its toolbar button. Once selected the question mark mouse pointer is displayed until a control is clicked. At that time a short description of the control is displayed. This display is removed by clicking the mouse again.

#### Tooltips

Tooltips are displayed by hovering the mouse over a control. Tooltips are only used where they add value.

#### Help Menus

Each window provides a Help menu for access to commonly requested help items.

## Help Buttons

Most dialog boxes have a Help button in the lower right corner. Pressing this button provides help for that dialog box.

## PDF Manual

The help provided online by WinSRFR is also available in PDF format. Both the online help and the PDF manual are produced from the same source so they provide the same content.

### 1.6.5.4 Data Table Entry

Data Tables are used throughout WinSRFR for entry and display of tabular data. They appear in Window's forms, as shown below, as well as in Dialog Boxes. Data can be entered manually, pasted from the clipboard or imported from a file. Once entered, data can be copied to the clipboard and exported to a file. It is important to remember that when data is imported or pasted into a Data Table, the new data must have compatible columns of data both in number and data type.

WinSRFR - Furrow - Measured advance and recession data (Merriam-Keller)

File Edit View Evaluation Help

Examples, Case: Tests  
Analysis: Merriam-Keller Analysis

**Advance Table**

Distance (m)	Time (hr)
0	0
25	0.15
50	0.29
75	0.48
100	0.65
125	0.84
200	1.03
175	1.22
200	1.4
225	1.65
250	1.96
275	2.25
300	2.65
325	2.96
350	3.24

**Recession Table**

Distance (m)	Time (hr)
0	10.23
25	10.25
50	10.2
75	10.04
100	9.9
125	9.75
150	9.71
200	9.65
225	10.71
250	10.74
275	10.77
300	10.78
325	10.8
350	10.82

**Opportunity Time Table**

Distance (m)*	Time (hr)*
0	10.23
25	10.25
50	10.2
75	10.04
100	9.9
125	9.75
150	9.71
200	9.65
175	9.41
200	9.28
225	9.06
250	8.78
275	8.52
300	8.13

Errors are indicated with a red icon. Hovering the mouse over the icon displays the error message.

Values in column "Distance (m)" must increase monotonically

Average = 8.3 hr

\* Calculated by WinSRFR

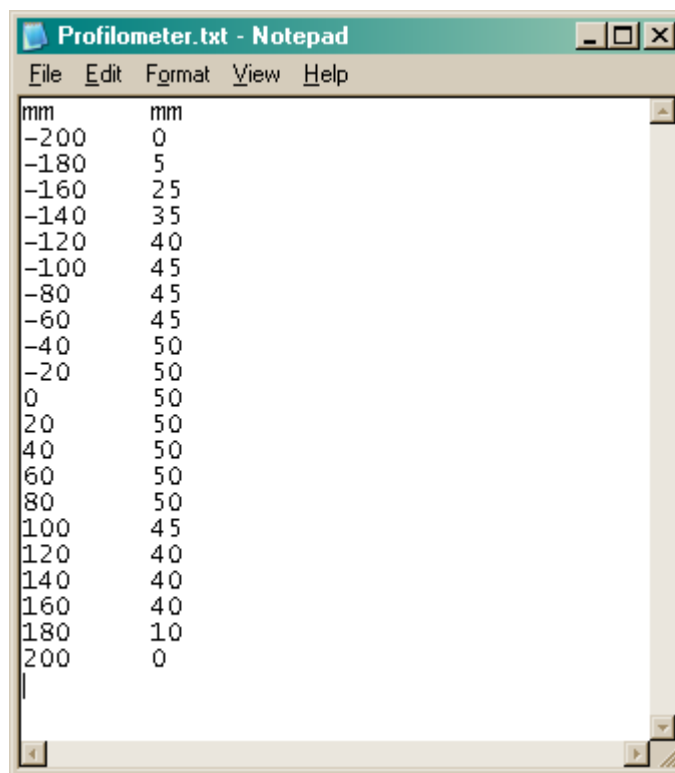
Move Advance Values to Recession Table

Event World System Geometry Soil Crop Properties Inflow / Runoff Advance / Recession Execution Results

No Results are available; Run the Analysis to generate the Results

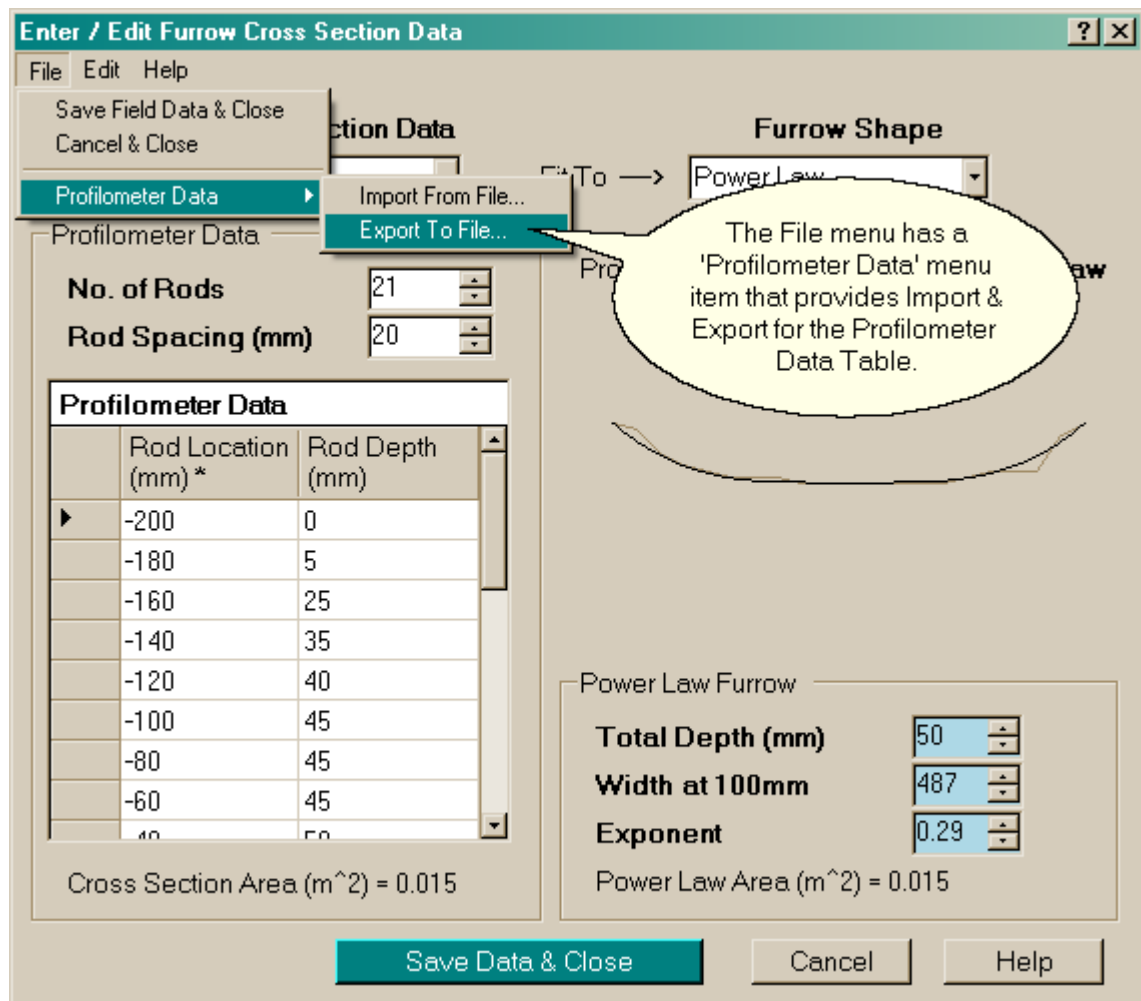
User Level: Advanced

Menu items for all Data Tables are found in the File and Edit menus as well as in [Context Menus](#). The File Menu is used for Importing and Exporting tabular data. There is File menu entry for every Data Table being displayed. The Data Table's name is displayed as the menu item's name.

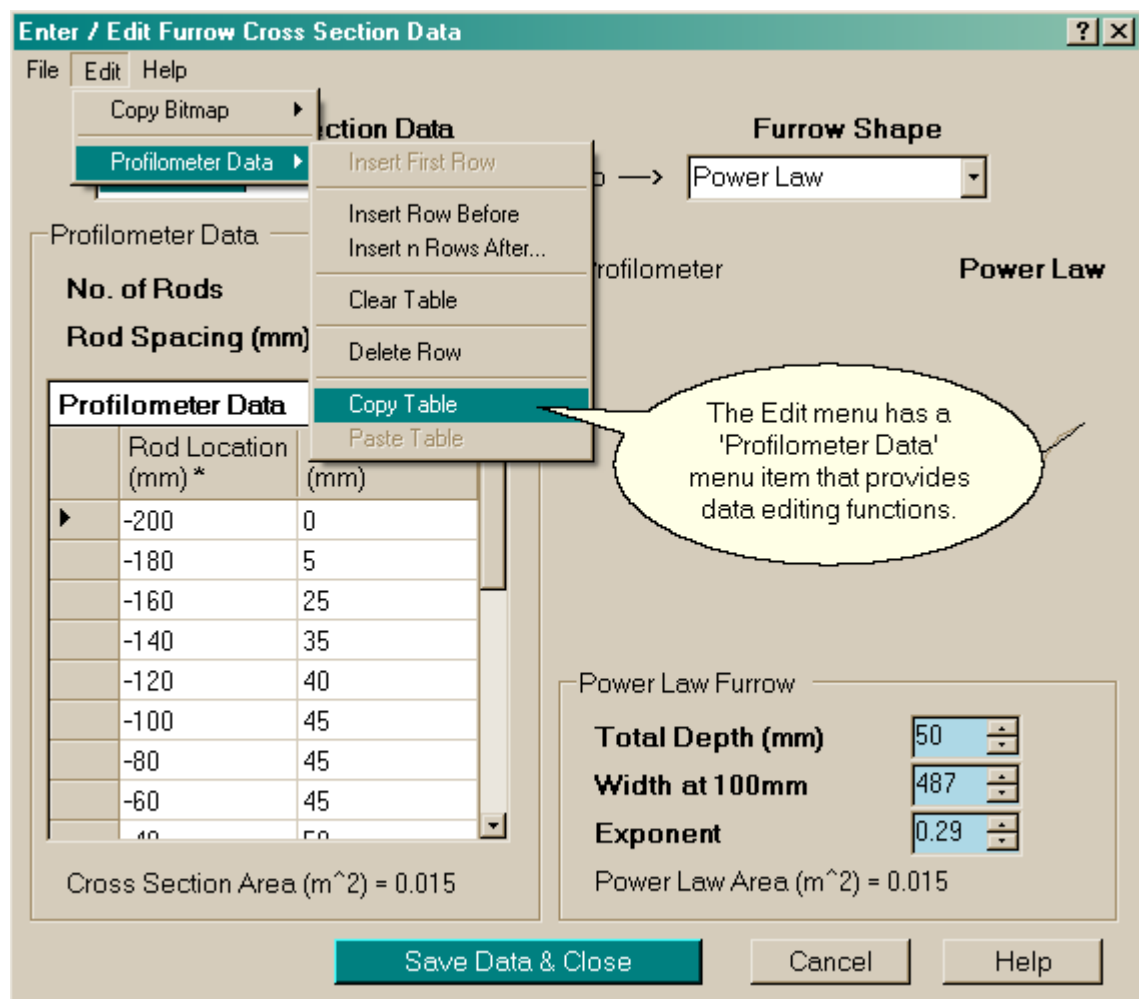


mm	mm
-200	0
-180	5
-160	25
-140	35
-120	40
-100	45
-80	45
-60	45
-40	50
-20	50
0	50
20	50
40	50
60	50
80	50
100	45
120	40
140	40
160	40
180	10
200	0

The file shown above contains data ready to be imported into a Profilometer Data table. Note that the first line in this file contains the units applicable to each column of data. If this line is present, the units specified will be used when the file is imported. If this line is missing, the units currently being displayed by WinSRFR will be used. Of course, a Profilometer Data file exported by WinSRFR can always be imported later. Files are checked to ensure they have a valid number of rows and columns and the right type of data in each column. Error message(s) will be displayed if the data is not valid or incompatible with the current setup.

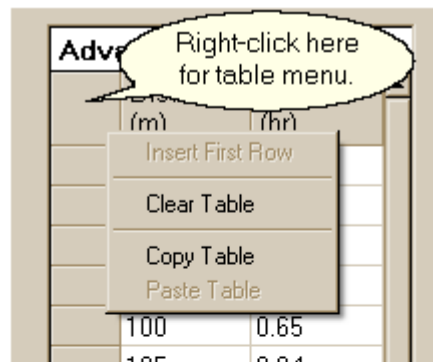


Similarly, the Edit Menu is used for inserting & deleting rows as well as for other editing functions such as Clear, Copy and Paste.

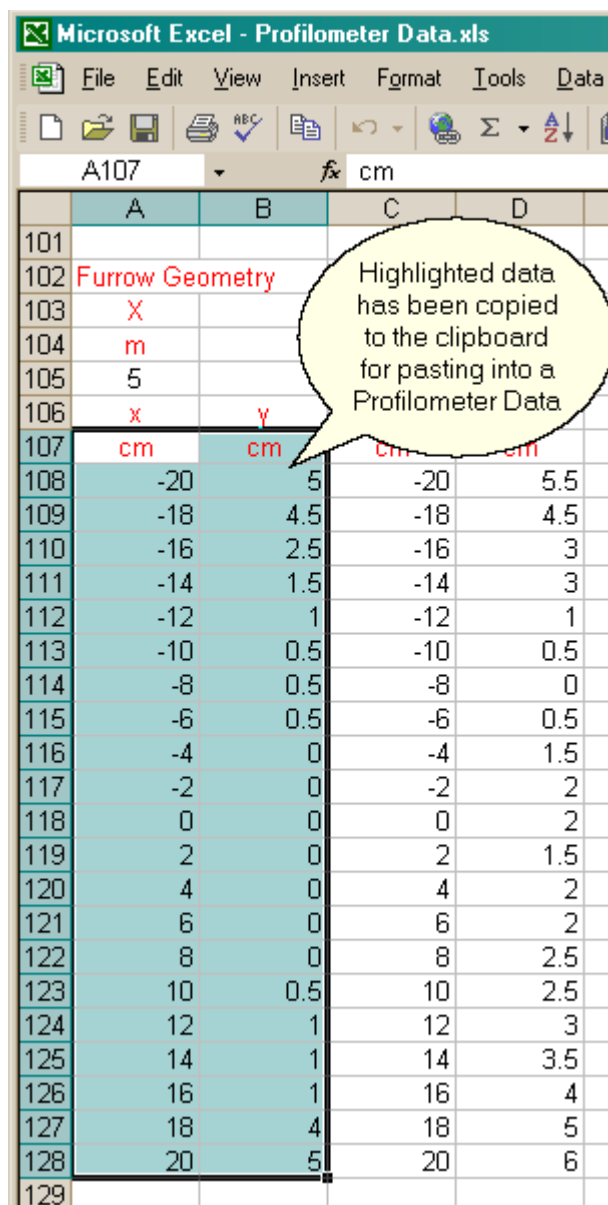


Besides being in the File and Edit menus, these functions are also available in [Context Menus](#) directly in the Data Table. Right-click with the mouse on the table or row to display the corresponding Context Menu.





When pasting data from an application like Excel, the first row may contain the units to apply to each column. If the units are copied to the clipboard, they will be used when pasting the data into WinSRFR. If the units are not copied, the row data will use the units currently being displayed by WinSRFR.



Microsoft Excel - Profilometer Data.xls

File Edit View Insert Format Tools Data

A107 fx cm

	A	B	C	D
101				
102	Furrow Geometry			
103	X			
104	m			
105	5			
106	x	y		
107	cm	cm	cm	cm
108	-20	5	-20	5.5
109	-18	4.5	-18	4.5
110	-16	2.5	-16	3
111	-14	1.5	-14	3
112	-12	1	-12	1
113	-10	0.5	-10	0.5
114	-8	0.5	-8	0
115	-6	0.5	-6	0.5
116	-4	0	-4	1.5
117	-2	0	-2	2
118	0	0	0	2
119	2	0	2	1.5
120	4	0	4	2
121	6	0	6	2
122	8	0	8	2.5
123	10	0.5	10	2.5
124	12	1	12	3
125	14	1	14	3.5
126	16	1	16	4
127	18	4	18	5
128	20	5	20	6
129				

#### 1.6.5.5 Cut / Copy / Paste

The Analysis Explorer uses Cut, Copy & Paste to:

- 1) Move item from one location to another (Cut & Paste)
- 2) Make a new copy of item (Copy & Paste)

For example, if you want to run a Simulation on the Border Design in the list shown below, perform these steps:

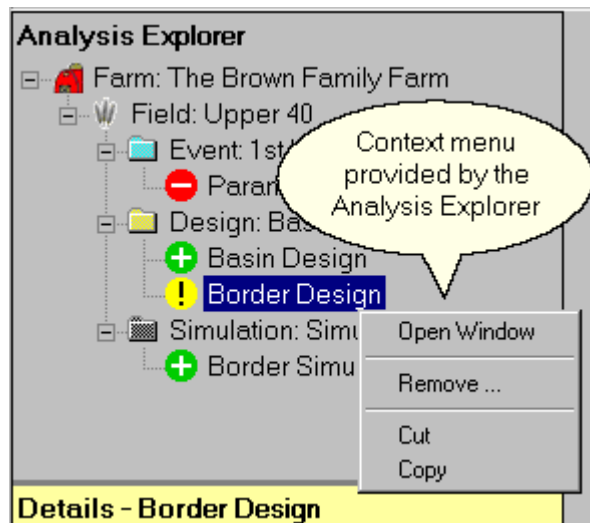
- a) Copy the Border Design to the clipboard using its Context Menu.
- b) Select a Simulation World Folder.
- c) Paste the Border Design into the Simulation World Folder using its Context Menu.

## Cut / Copy

To Cut or Copy, right-click on an Analysis or Simulation then select Cut or Copy in the context menu.

Pressing the space bar also displays the context menu for the selected item in the Analysis Explorer. Use the arrow keys to choose the menu item then press Enter to invoke it.

Cut & Copy are also available for World Folders and Fields.

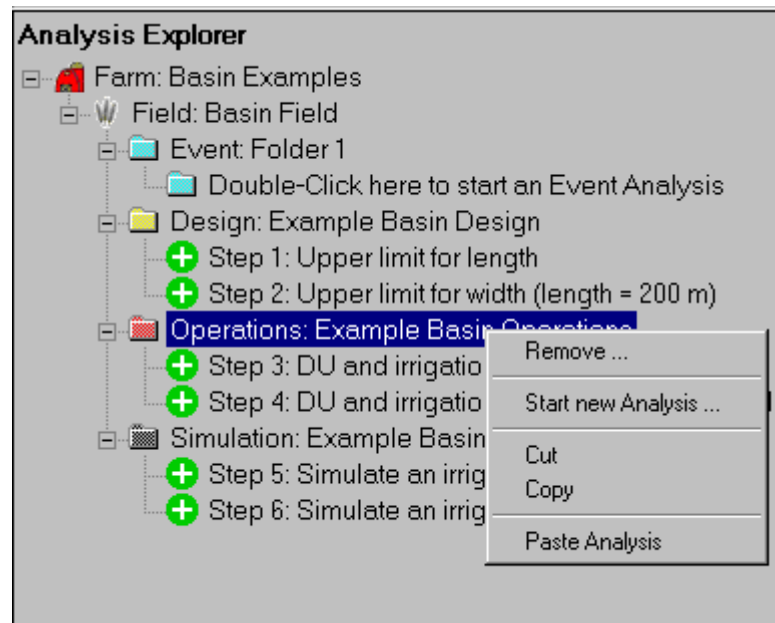


## Paste

To Paste, right-click on a World Folder then select Paste Analysis or Simulation in the context menu.

Pressing the space bar also displays the context menu for the selected item in the Analysis Explorer. Use the arrow keys to choose the menu item then press Enter to invoke it.

Paste is also available for pasting World Folders into Fields & Fields into Farms.



The new item keeps the same name, if possible; you may want to modify this using the Details view shown below the Analysis Explorer.

Note - If an item with the same name is already in the folder, the pasted item's name will be modified by appending a sequence number.

## 1.6.6 Dialog Boxes

Most WinSRFR dialog boxes have a Help button in the lower-right corner that displays a help page describing its use.

Help is available for the following dialog boxes:

- [User Preferences](#)
- [Units](#)
- [Match Infiltration Method](#)
- [Edit Furrow Crosssection Data](#)
- [Vary With Distance & Time](#)
- [Slope / Elevation Table Entry](#)
- [Choose Solution](#)

### 1.6.6.1 User Preferences

The User Preferences dialog box provides access to user-customized aspects and defaults for WinSRFR's User Interface and function execution. These preferences vary from user to user on the same PC as they are stored in the Current User section of the Window's Registry. Some user preferences only take effect when WinSRFR is started so changes may not be seen until you close and restart WinSRFR. These settings, however, have menu items that change the preferences immediately (Units is one example).

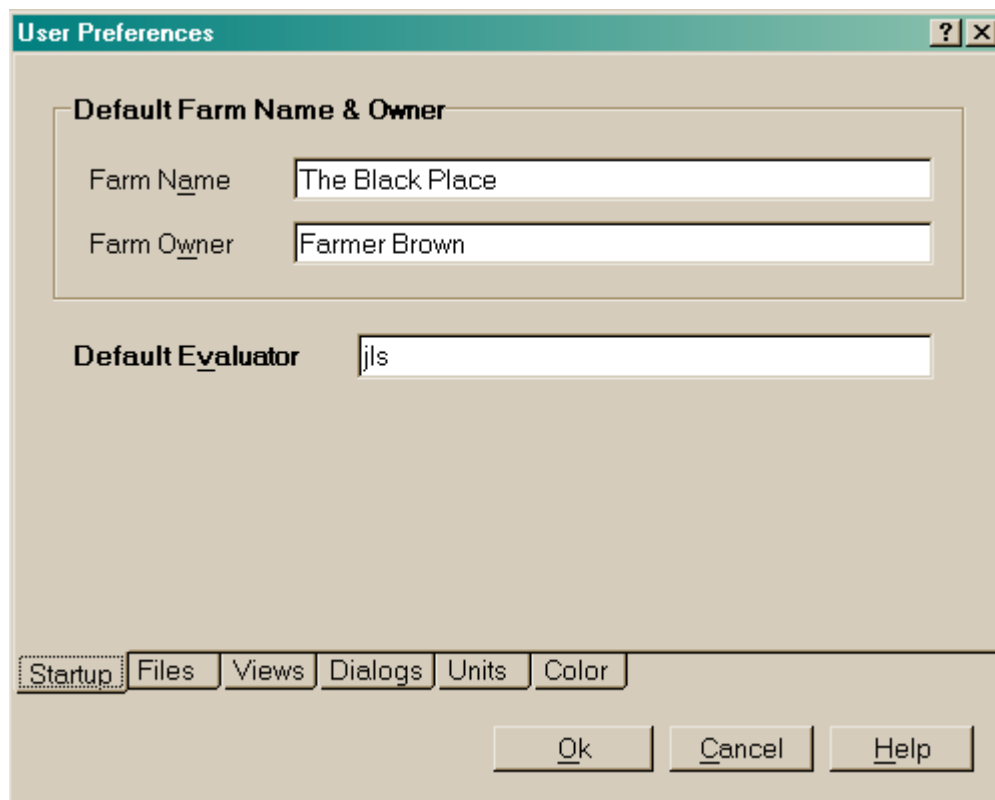
The User Preferences are grouped on six tabs depending on their use and application:

- Startup - Default values for application-wide data
- Files - Paths to commonly used files / folders
- View - Options for enabling / disabling and controlling WinSRFR views
- Dialogs - Options controlling whether or not certain dialog boxes are displayed
- Units - Units system and default units selection
- Color - Colors to use for graphs

Each tab and its User Preferences are listed below.

### Startup Tab

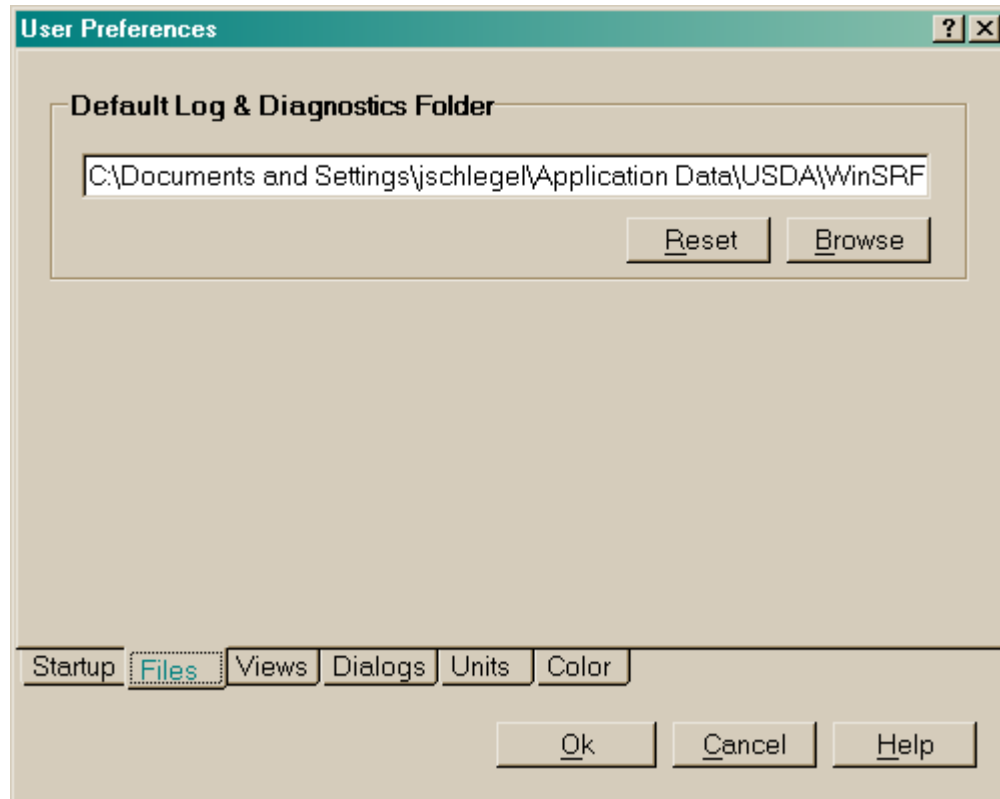
- Farm Name - default name used when a new Farm / Project is created
- Farm Owner - default name used for the Farm's Owner
- Evaluator - default name of the person running WinSRFR; this name is used whenever a new Analysis / Simulation is created



The screenshot shows the 'User Preferences' dialog box with the 'Startup' tab selected. The dialog has a title bar with a question mark and a close button. The main area is divided into two sections. The first section, 'Default Farm Name & Owner', contains two text input fields: 'Farm Name' with the value 'The Black Place' and 'Farm Owner' with the value 'Farmer Brown'. The second section, 'Default Evaluator', contains a text input field with the value 'jls'. At the bottom of the dialog, there is a row of six tabs: 'Startup', 'Files', 'Views', 'Dialogs', 'Units', and 'Color'. The 'Startup' tab is currently selected. Below the tabs are three buttons: 'Ok', 'Cancel', and 'Help'.

## Files Tab

Default Log & Diagnostic Folder - path to the folder for WinSRFR's log and diagnostics files.

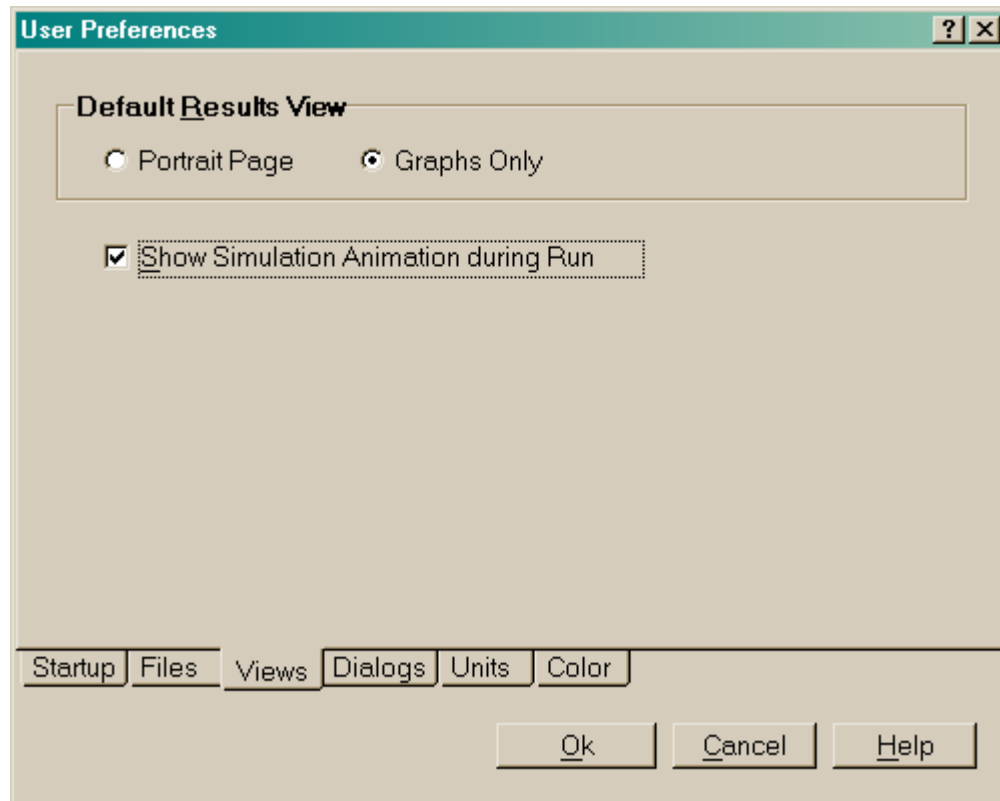


## Views Tab

### Default Results View

- Portrait Page - all Results are displayed on a Portrait page (Print Preview-like view)
- Graphs Only - graphs fill the available window; text results display on a Portrait page

Show Simulation Animation during Run - selects whether or not the Simulation Animation will automatically display when a Simulation is run



## Dialogs Tab

**Suggested Default Values** - controls whether or not to confirm suggested changes to the Solution Model or Cell Density when running a Simulation

Unconditionally Accept - use suggested default values without confirmation

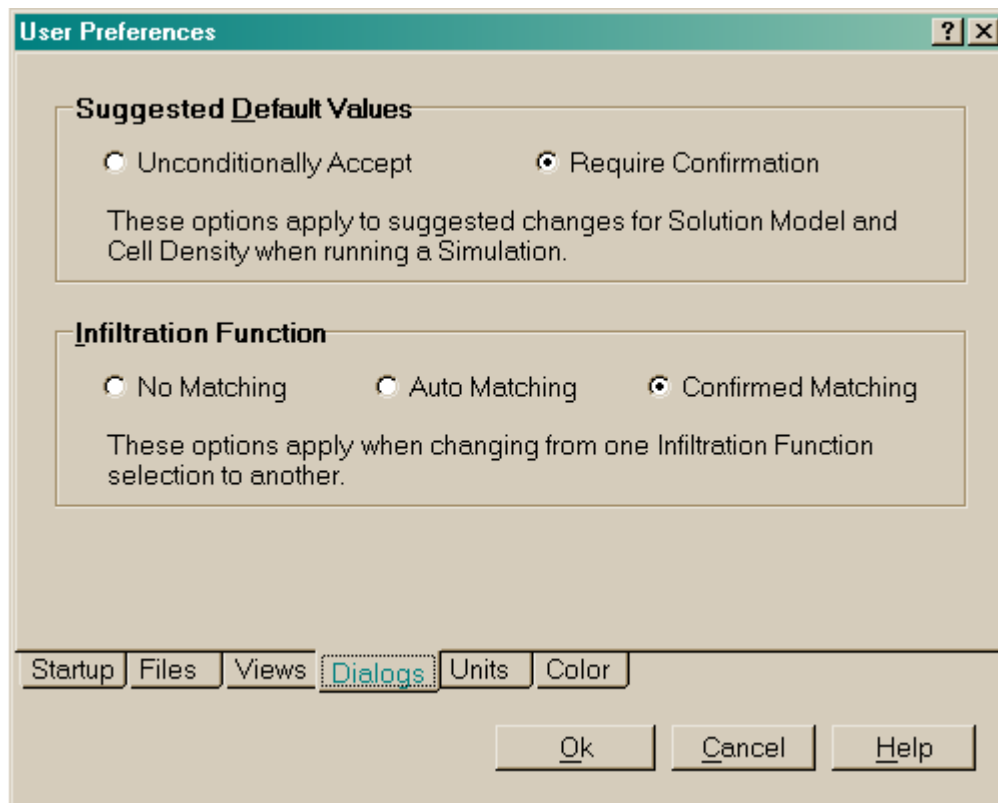
Require Confirmation - display dialog box to confirm changes

**Infiltration Function** - controls what happens when a new Infiltration Function is selected.

No Matching - keeps Infiltration Function parameters independent from selection to selection

Auto Matching - automatically matches parameters for new Infiltration Function with old function

Confirmed Matching - displays dialog box to confirm changes



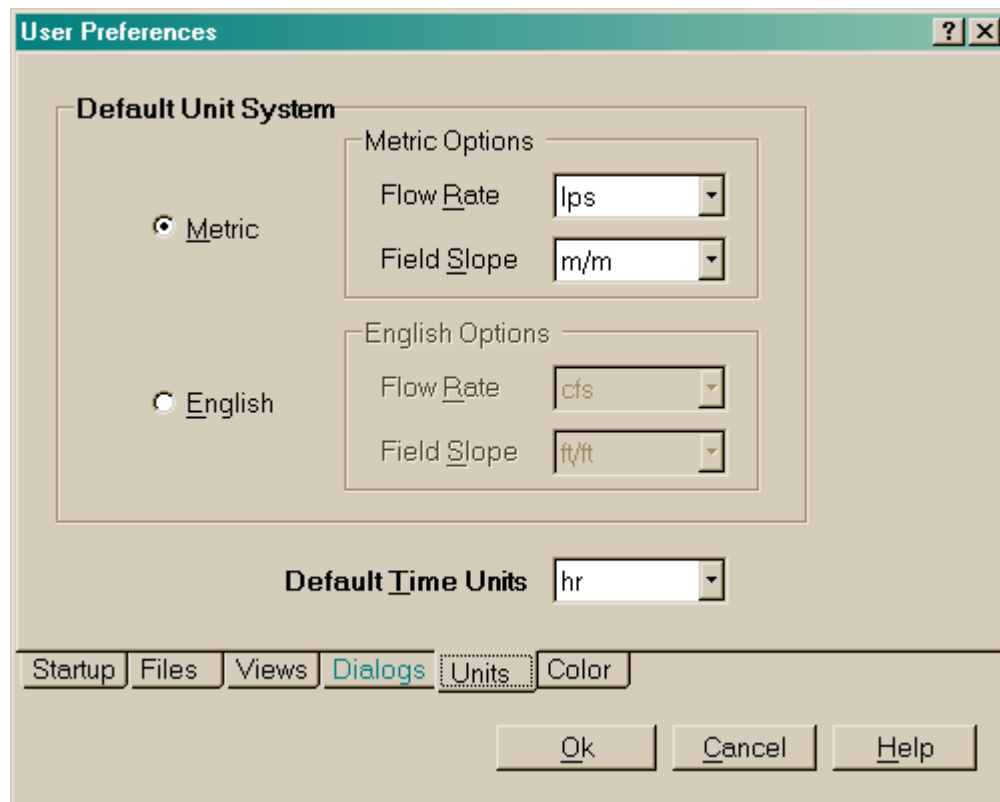


## Units Tab

Default Unit System - selects whether Metric or English units are used as the default units system

Options - allows selection of individual units for specific data types

Default Time Units - selects whether Hours or Minutes are used as the default time units



The image shows a 'User Preferences' dialog box with the 'Units' tab selected. The dialog has a title bar with a question mark and a close button. The main content area is divided into two sections: 'Default Unit System' and 'Default Time Units'. In the 'Default Unit System' section, there are two radio buttons: 'Metric' (selected) and 'English'. To the right of these are two groups of options. The 'Metric Options' group contains 'Flow Rate' set to 'lps' and 'Field Slope' set to 'm/m'. The 'English Options' group contains 'Flow Rate' set to 'cfs' and 'Field Slope' set to 'ft/ft'. Below these is the 'Default Time Units' section, which has a dropdown menu currently set to 'hr'. At the bottom of the dialog, there is a row of tabs: 'Startup', 'Files', 'Views', 'Dialogs' (highlighted in blue), 'Units' (active), and 'Color'. Below the tabs are three buttons: 'Ok', 'Cancel', and 'Help'.

Default Unit System	
<input checked="" type="radio"/> Metric	<div>Metric Options</div> <div>Flow Rate: lps</div> <div>Field Slope: m/m</div>
<input type="radio"/> English	<div>English Options</div> <div>Flow Rate: cfs</div> <div>Field Slope: ft/ft</div>

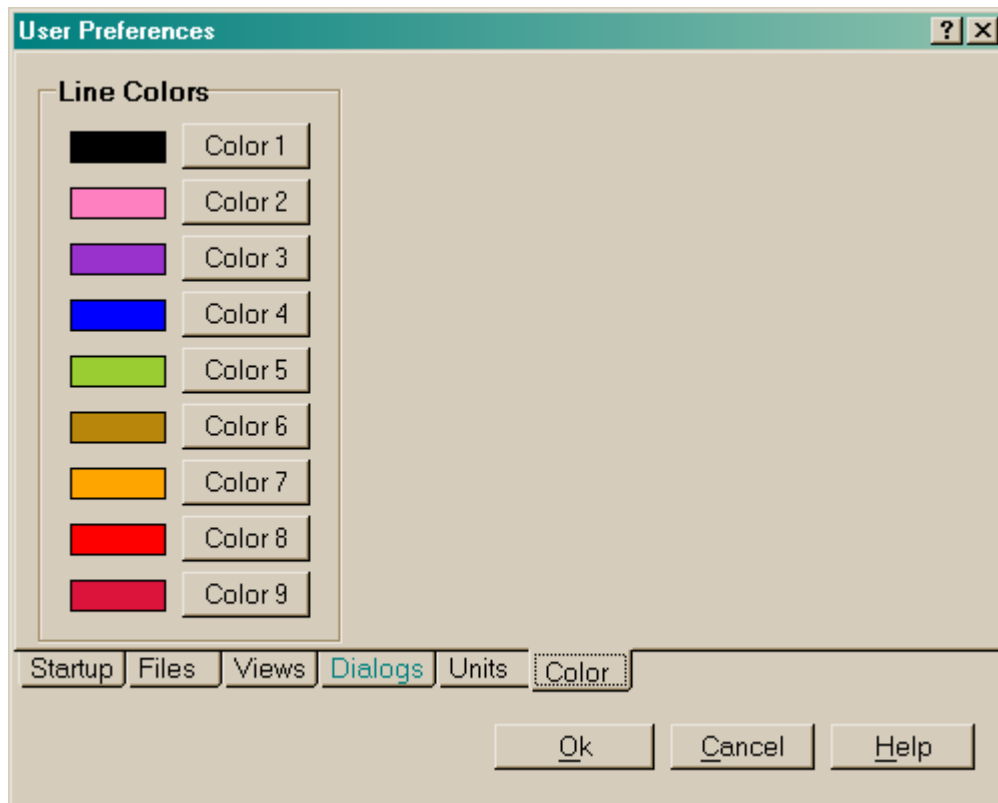
Default Time Units: hr

Startup | Files | Views | Dialogs | **Units** | Color

Ok | Cancel | Help

## Color Tab

Line Colors - selects the colors for individual lines when drawing graphs. Colors are used in the order shown when multiple parameters are drawn on the same graph.



### 1.6.6.2 Units Dialog Box

WinSRFR provides the option of working in either Metric or English units with additional options available under each. Use the radio button to select the Unit System and the drop-down controls to select the desired options.

Pressing the Ok button will apply your selections and close the dialog box.

Pressing the Apply button will apply your selections and leave the dialog box displayed so more changes can be made.

Pressing the Close button will close the dialog box without applying the last set of changes.

**Select Unit System & Options**

Unit System

☐ Metric

☒ English

Metric Units

Flow Rate: lps

Field Slope: m/m

English Units

Flow Rate: cfs

Field Slope: ft/ft

Time Units: hr

Ok Apply Close

### 1.6.6.3 Match Infiltration Method

In WinSRFR, there are six methods, selected using the [Soil / Crop Properties](#) tab, for specifying how water infiltrates into the soil:

1. Known Characteristic Infiltration Time
2. NRCS Intake Family
3. Time-Rated Infiltration Family
4. Kostiakov Formula
5. Modified Kostiakov Formula
6. Branch Function

When the Infiltration Method is changed, one of three operations occurs depending on the choice made using the [User Preference's](#) Dialogs tab:

1. No Matching
2. Automatic Matching
3. Confirmed Matching

Unless No Matching is selected, when a new method is chosen, WinSRFR selects infiltration parameters so the new method matches the old method as closely as possible. When Confirmed Matching is selected, the following dialog box is displayed allowing you to verify and adjust, if necessary, the newly selected infiltration parameters.

**Select / Match Infiltration Function Parameters**

A new Infiltration Function has been selected and an initial 'best match' between the new & old methods has been provided. Use the controls below to make required adjustments while viewing the graph to the right to compare the old & new infiltration functions.

**Known Characteristic Infiltration Time**

Kostiakov  $k = 32.299 \text{ mm/hr}^a$

Characteristic Infiltration Depth  mm

Corresponding Infiltration Time  hr

" Kostiakov  $a$

Disable dialog box using User Preferences' Dialogs tab.

This dialog box is displayed so that the old method is viewable below the graph and the new method is displayed to the left of the graph. The graph will contain a line for each Infiltration Method. Adjust the parameters of the new Infiltration Method in the dialog box while viewing the results of the change in the graph. When the new Infiltration Method meets your needs, press Ok to complete the change. Press Cancel at any time to abort the change.

#### 1.6.6.4 Edit Furrow Cross Section Data

WinSRFR defines the cross section of a furrow as either a trapezoid or power law function. These two methods are convenient for mathematical operations but may not be easy to define. The **Enter / Edit Furrow Cross Section Data** dialog box enables entering furrow cross section data as measured in the field which WinSRFR then will use to calculate a 'best fit' to either a trapezoid or power law function.

Three methods are available for entering furrow cross section data:

1. Depth / Width Table - a series of furrow depth / width pairs
2. Profilometer Table - furrow depths as measured using a Profilometer
3. Top / Middle / Bottom widths with a single Depth

**Enter / Edit Furrow Cross Section Data**

File Edit Help

**Furrow Cross Section Data**  
 Profilometer — Fit To —> **Furrow Shape**  
 Power Law

Profilometer Data  
 No. of Rods: 21  
 Rod Spacing (mm): 20

Profilometer Data		
	Rod Location (mm) *	Rod Depth (mm)
▶	-200	6
	-180	14
	-160	18
	-140	26
	-120	24
	-100	66
	-80	96
	-60	102
	-40	100

Cross Section Area (m<sup>2</sup>) = 0.025

Profilometer Power Law

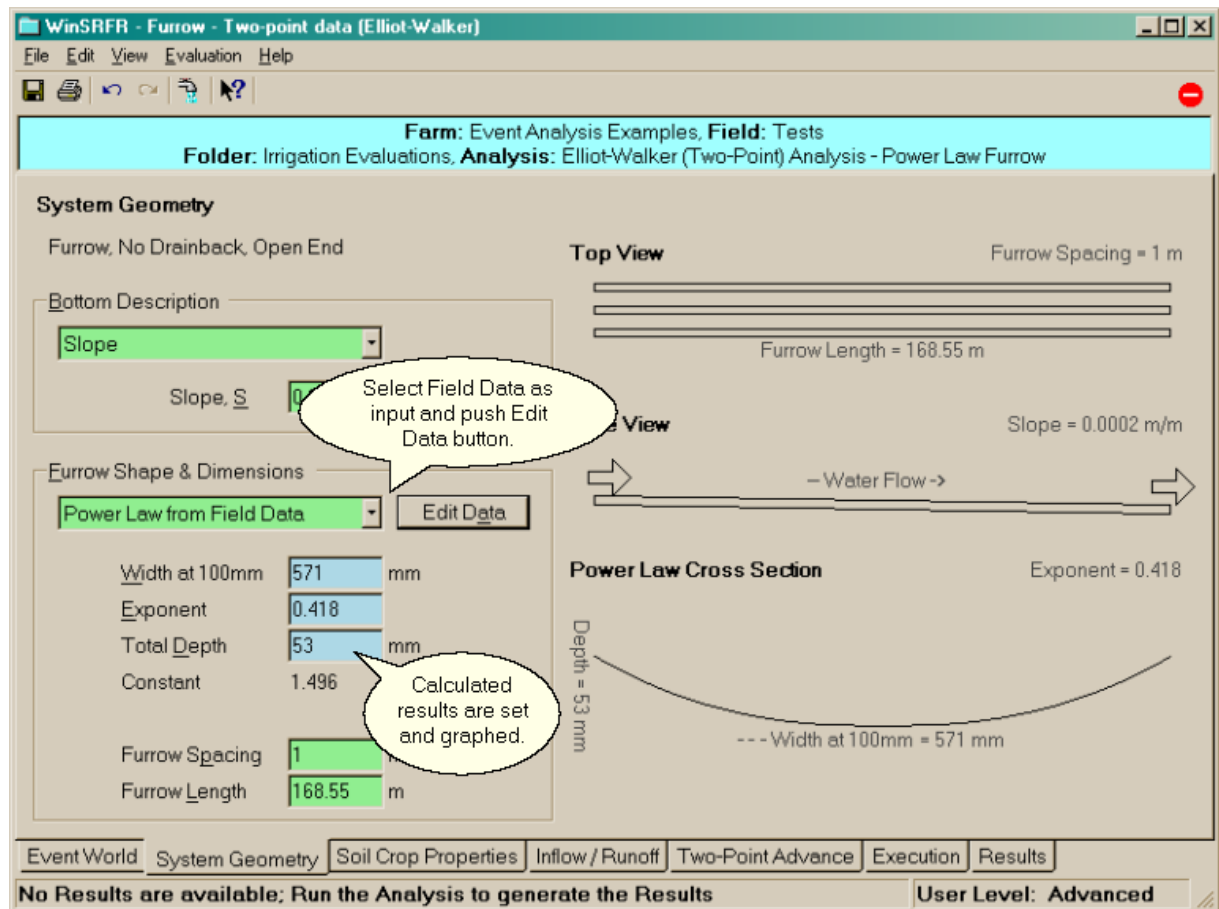
Power Law Furrow  
 Width at 100mm (mm): 335  
 Exponent: 0.34  
 Total Depth (mm): 94  
 Power Law Area (m<sup>2</sup>) = 0.023

Save Data & Close Cancel Help

The entered cross section data can be fitted to either a trapezoid or power law function. WinSRFR calculated values are displayed in blue but can be modified if a different fit is desired; modified values are displayed in green.

Once the desired fit has been achieved, press the **"Save Data & Close"** button to transfer this data back to the WinSRFR Analysis or Simulation. To exit the dialog box, press the **"Cancel"** button. The **"Cancel"** button simply closes the dialog box with no further action; any changed values will be lost.

This dialog box is accessed using the System Geometry tab. Select either "**Power Law from Field Data**" either "**Trapezoid from Field Data**", then press then "**Edit Data**" button to bring up the dialog box.



### 1.6.6.5 Vary With Distance & Time

Some parameters within WinSRFR can be specified as either a single constant or as a table. Slope within [System Geometry](#) is one example. Slope can be a constant or it can be specified as a Slope Table or an Elevation Table as shown below.

In Version 1.0 of WinSRFR, these parameters can vary only by distance down the field. Variation by time is not supported.

	Distance (m)	Elevation (m)
▶	0	0.03
	15.24	0.02
	45.72	0.03
	76.2	0.03
	106.68	0.02
	137.16	0.04
	167.64	0.02
	185.93	0.03

Field Length = 185.93 m

Vary Elevation By ...

☒ Distance Only ☐ Distance & Time

Ok Cancel Help

Operations, such as Copy & Paste and Insert & Delete, are available using either the menu bar or via right-click context menus.

Some restrictions on data entry may be in place depending on the minimum & maximum number of rows and on whether or not rows are required for the start and/or end of the field. These restrictions vary from parameter to parameter.

### 1.6.6.6 Slope / Elevation Table Entry

A field's Slope, specified using the [System Geometry](#) tab, can be a constant value from the start of the field to its end or it can vary with distance down the field. In WinSRFR, Slope is expressed as a constant or as a Slope Table or Elevation Table as shown below. The Slope Table and the Elevation Table are merely different ways of viewing and editing the same tabular data. Only one set of slope data table is stored within WinSRFR for each field. Tabulated Elevation data can be entered and stored then viewed as a Slope Table and vice versa.

Slope Table

File Edit

	Distance (m)	Slope (m/m)
▶	0	0.0028
	25	0.0032
	50	0.0024
	75	0.0036
	100	0.0044
	125	0.004
	150	0.004
	175	0.0052

Field Length = 625 m

Vary Slope By ...

☒ Distance Only ☐ Distance & Time

Ok Cancel Help

Elevation Table

File Edit

	Distance (m)	Elevation (m)
▶	0	10
	25	9.93
	50	9.85
	75	9.79
	100	9.7
	125	9.59
	150	9.49
	175	9.39

Field Length = 625 m

Vary Elevation By ...

☒ Distance Only ☐ Distance & Time

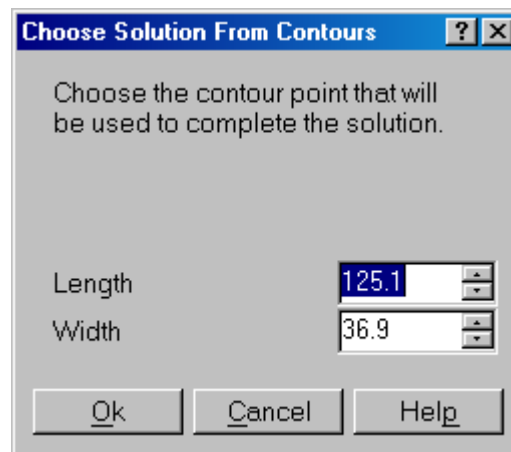
Ok Cancel Help



### 1.6.6.7 Choose Solution

When working with Border fields in either the [Physical Design](#) or [Operations Analysis](#) Worlds, a Run produces contour graphs of many possible solutions for your irrigation needs. To evaluate a single solution, the Choose Solution dialog box lets you select a single point within the contours.

A Water Distribution Diagram for this point will then be added to the [Results](#).



### 1.6.7 Keyboard Navigation

WinSRFR can be operated using the keyboard alone; use of the mouse is not required. Some of the ways a user can navigate the various windows and dialog boxes using only the keyboard are documented below.

#### Menus

To activate any Menu item:

- 1) Press and release the "Alt" key. This selects the first menu in the menu bar and underlines the activation keys for all menu items.
  - 2a) Use the arrow keys to traverse the menu to select the item you want then press the "Enter" key.
- or
- 2b) Press the underlined activation key for the desired menu item.

#### Tab Pages

To select a tab page:

- 1) Use the "Tab" key to move focus to the tabs.
- 2) Use the arrow keys to select the tab page.

## Numeric Controls

To select a numeric entry control:

1a) Use the "Tab" key to move the focus to the control. "Tab" moves the focus forward while "Shift-Tab" moves focus backward.

or

1b) Use the "Alt" as you would the shift key to select the numeric control. All controls have an associated activation key; this is the letter underlined in the control's label. For example, "Alt-W" will select the control with "W" underlined. The "Tab" key may be needed to selected a particular control if it is in a group of controls that share a single label.

To edit the value of a numeric entry control:

2) When a numeric control has focus, its value is usually highlighted. You can simply type in a new value at this point or use the arrow keys to position the cursor to a point where you can edit the current value.

3a) Press "Enter". The new value will be entered and focus will stay on the control.

or

3b) Press "Tab". The new value will be entered and focus will move to the next control.

## Selection Controls

To select a selection control:

1a) Use the "Tab" key to move the focus to the control. "Tab" moves the focus forward while "Shift-Tab" moves focus backward.

or

1b) Use the "Alt" as you would the shift key to select the control. All controls have an associated activation key; this is the letter underlined in the control's label. For example, "Alt-S" will select the control with "S" underlined. The "Tab" key may be needed to selected a particular control if it is in a group of controls share a single label.

To edit the value of a selection control:

2) Use the arrow keys to move through the selections.

## Check Box Controls

To change the state of a check box control:

1) Use the "Tab" key to move focus to the check box.

2) Use the "Space bar" to change the state.

## Buttons

To press a button:

1a) Use the "Tab" key to move the focus to the button. "Tab" moves the focus forward while "Shift-Tab" moves focus backward.

or

1b) Use the "Alt" as you would the shift key to press the button. All buttons have an associated activation key; this is the letter underlined in the button's label. For example, "Alt-A" will press the button with "A" underlined.

## Analysis Explorer

To use the [Project Management window's Analysis Explorer](#):

1) Use the "Tab" key to move the focus to the Analysis Explorer. "Tab" moves the focus forward while "Shift-Tab" moves focus backward.

2) Use the arrow keys to move around in the explorer. The up and down arrows move through the visible items. The left moves up through the items closing levels as it goes. The right arrow moves down through the items opening levels as it goes.

3a) Once you have selected an Analysis or Simulation, press the "Enter" key to display it in its corresponding WinSRFR World.

or

3b) Press the "Space bar" to display the [Context Menu](#) associated with the item. Use the arrow keys to select the Context Menu item then press "Enter" to activate that item. Press the escape key, "Esc", to remove the Context Menu.

## Function / Control Keys

Some functions can be accessed directly by using function or control keys:

F1                - Help

### Analysis Explorer

Ctrl-X          - Cut  
Ctrl-C          - Copy  
Ctrl-V          - Paste

### Results Tab

Ctrl-F          - Portrait layout  
Ctrl-L          - Landscape layout  
Ctrl-G          - Graphics layout

### World Windows

- Ctrl-P        - Print
- Ctrl-R        - Run the Analysis or Simulation
- Ctrl-W        - Display the main WinSRFR Project Management Window

### All Windows

- Ctrl-S        - Save
- Ctrl-Y        - Redo
- Ctrl-Z        - Undo

## 2 Common Tasks

This section provides help for getting started using WinSRFR's functionality. Each topic provides a series of steps to help you understand how to use WinSRFR to improve your surface irrigations. Topics include:

### Working with Furrows

- [Evaluate a Furrow Irrigation](#)
- [Simulate a Furrow Irrigation](#)

### Working with Basin Fields

- [Design a Basin Field](#)
- [Operate a Basin Irrigation](#)
- [Simulate a Basin Irrigation](#)

### Working with Border Fields

- [Design a Border Field](#)
- [Operate a Border Irrigation](#)
- [Simulate a Border Irrigation](#)

## 2.1 Evaluate a Furrow Irrigation

Evaluate a Furrow Irrigation describes how to evaluate the performance of an irrigation of a furrow as well as estimate the Modified Kostiakov Formula parameters that describe the infiltration of water into the furrow's soil.

You should open the WinSRFR file, **Event Analysis Examples.srfr**, installed under WinSRFR/Examples to view the analyses described in this section..

All event analyses start in the same manner:

1. **Event World** Tab - select the system type (Cross Section, Upstream & Downstream Conditions) and the desired analysis type.
2. **System Geometry** Tab - enter the field's physical dimensions (Length, Width & Slope).
3. **Soil / Crop Properties** Tab - enter the field's surface roughness and perhaps its soil's infiltration characteristics.
4. **Inflow / Runoff** Tab - enter either the Standard Hydrograph or Tabulated Inflow data describing the irrigation water's flow onto the field. For Open-End fields, enter the Tabulated Runoff, if any, that occurred during the irrigation.

The next tab varies depending on the analysis type selected in step 1.

### Probe Penetration Analysis:

5. **Probe Measurements** Tab - enter the field's pre-irrigation soil water depletion data and the post-irrigation probe depths.

### Merriam-Keller Analysis: (Includes estimation of Kostiakov k)

5. **Advance / Recession** Tab - enter the tabulated advance & recession data measured during the irrigation.

### Elliot-Walker Analysis: (Includes estimation of Kostiakov k, a & b)

5. **Two-Point Data** Tab - enter the two-point advance data measured during the irrigation.

After all you data has been entered, proceed to the **Execution** tab to Run the analysis. If Kostiakov infiltration parameters were estimated, you can also verify the accuracy of the estimations.

## 2.2 Simulate a Furrow Irrigation

Simulate a Furrow Field is similar to [Simulate a Border Field](#), except furrows are used within the border.

You may open the WinSRFR file, **Furrow Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

**Objective:** Simulate the operating conditions of a single furrow within the following border field.

**Border Dimensions:** 40m wide by 400m long

**Furrow Dimensions:** 1.25m spacing, 400m long, Trapezoid shaped

**Anticipated Cropping Pattern:** Bare soil yields a resistance to flow represented by a Manning n of 0.04.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov a of 0.5.

**Available Flow Rate to Borders:** 230 lps

**AE:** 80%

**Step 1:** Simulate the operating conditions of a single furrow within the following border field.

Enter field conditions and run criteria:

Simulation World Tab

Cross Section = Furrow

Upstream Condition = No Drainback

Downstream Condition = Open End

System Geometry Tab

Slope, S: 0.0005 m/m

Furrow Shape: Trapezoid

Bottom Width, W: 300 mm

Side Slope: 1.5 H/V

Maximum Depth 300 mm

Furrow Spacing: 1.25 m

Furrow Length: 400 m

Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select 0.04 - Bare Soil

Infiltration Method: Known Characteristic Infiltration Time

Char. Infiltration Depth: 100 mm

Corr. Infiltration Time: 3.5 hr (210 min)

Corr. Kostiakov a: 0.5

Inflow Management Tab:

Required Depth, Dreq: 100 mm

Inflow Rate, Q: 4 lps  
Cutoff Time, Tco: 8 hr

Data Summary Tab  
Verify all values on one tab

Execution Tab:

Press Run Button

Results Tab:  
View the various results tabs.

Rerun with other Inflow Rates & Cutoff Times.



## 2.3 Design a Basin Field

Design a Basin Field is based on **Chapter 4 - Example Design** from the WCL Report #19, **BASIN - A Computer Program for the Design of Level-Basin Irrigation Systems - Version 2.0** published by the USDA / ARS / US Water Conservation Laboratory in Phoenix, AZ. This example design and operation of a level-basin is followed step-by-step but is updated for use with WinSRFR.

You may open the WinSRFR file, **Basin Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

**Design Objective:** Determine the optimal basin size for the following field and design conditions.

**Field Dimensions:** 600 m wide by 1200 m long

**Basin Dimensions:** To Be Determined (TBD)

**Anticipated Cropping Pattern:** A variety of crops will be grown with alfalfa creating the most resistance to flow; thus, a Manning n of 0.15 would be selected for this condition. A Manning n of 0.04 is used for anticipated smooth conditions or level furrows used within the basins.

**Soil Conditions:** For the given soil and crops, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov exponent, a, of 0.5.

**Available Flow Rate to Basins:** 230 lps

**Design DU:** 80%

**Step 1:** Determine the upper limit for basin length.

Create a new, default Design Analysis in a Design World Folder using either WinSRFR's Edit menu or the World Folder's right-click context menu. Name this analysis "Step 1".

Enter field conditions and run criteria:

Design World Tab

Cross Section = Basin

Upstream Condition = No Drainback

Downstream Condition = Blocked End

Select:

I want to ... Find the maximum limits for a field's dimensions.

I know ... Q, DU, Dreq

Soil / Crop Properties Tab

Roughness Method: NRCS Suggested Manning n

Select 0.15 - Alfalfa

Infiltration Method: Known Characteristic Infiltration Time

Char. Infiltration Depth: 100 mm

Corr. Infiltration Time: 3.5 hr (210 min)

Corr. Kostiakov a: 0.5

Inflow Management Tab:

Required Depth, Dreq: 100 mm

Inflow Rate, Q: 230 lps

Execution Tab:

Verify Dreq = 100 mm & Q = 230 lps

Set DU to 0.8 (80%)

Press Run Button

Results Tab:

View under Design Results: Length = 229.4 m & Width = 62.68 m

The **maximum** basin length & width recommended by WinSRFR for the defined field conditions are 229.4 m and 62.68 m respectively.

A length of 200 m will be chosen in Step 2 since 200 m is the largest length less than 229.4 m that is evenly divisible into 1200 m, the length of the entire field. (see Field Dimension above).

**Step 2:** Determine the upper limit for basin width for length = 200 m.

Copy the Design Analysis from Step 1 and Paste it into the same Design World Folder. Name this analysis "Step 2". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

Design World Tab

Select:

I want to... Determine a reasonable general design for a field.

I know... L, Q, DU, Dreq

System Geometry Tab

Set Length, L: 200 m

Verify Width, W: TBD

Execution Tab:

Verify Dreq = 100 mm, L = 200 m, Q = 230 lps & DU = 0.8

Press Run Button

Results Tab:

View under Design Results: Width = 84.16 m

For a 200 m long field, the maximum basin width recommended by WinSRFR for the defined field conditions is 84.16 m.

A width of 75 m will be chosen in Step 3 since 75 m is the largest width less than 84.16 m that is evenly divisible into 600 m, the width of the entire field. (see Field Dimension above).

The result of these two design steps is a recommended basin size of 75 m by 200 m. 48 such basins completely fill the 600 m by 1200 m field yielding irrigation Distribution Uniformities of at least 80%.

To continue this example, proceed to [Operate a Basin Irrigation](#).

## 2.4 Operate a Basin Irrigation

Operate a Basin Irrigation is based on **Chapter 4 - Example Design** from the WCL Report #19, ***BASIN - A Computer Program for the Design of Level-Basin Irrigation Systems - Version 2.0*** published by the USDA / ARS / US Water Conservation Laboratory in Phoenix, AZ. This example design and operation of a level-basin is followed step-by-step but is updated for use with WinSRFR.

You may open the WinSRFR file, **Basin Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

This example is continued from [Design a Basin Irrigation](#).

**Operations Objective:** Determine the operating conditions for the following basin field.

**Basin Dimensions:** 75 m wide by 200 m long

**Anticipated Cropping Pattern:** A variety of crops will be grown with alfalfa creating the most resistance to flow; thus, a Manning n of 0.15 would be selected for this condition. A Manning n of 0.04 is used for anticipated smooth conditions or level furrows used within the basins.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov exponent, a, of 0.5.

**Available Flow Rate to Basins:** 230 lps

**Step 3:** Determine the DU and irrigation guidelines for previously designed basin when growing alfalfa.

Copy the Design Analysis from [Design a Basin Irrigation](#), Step 2 and Paste it into a new Operations World Folder. Name this analysis "Step 3". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

Operations World Tab

Select:

I want to... Optimize an irrigation for a set Inflow Rate or DU.

I know... L, W, Q, Dreq

System Geometry Tab

Length, L: 200 m

Width, W: 75 m

Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select **0.15 - Alfalfa**

Execution Tab:

Verify Dreq = 100 mm, L = 200 m, W = 75 m & Q = 230 lps

Press Run Button

## Results Tab:

View under Operations Results:

DU = 81.1%

Cutoff Time (Tco) = 2.23 hr (134 min)

Advance Time = 2.74 hr (164 min)

Advance Distance at Tco = 176.21 m

Advance Distance Ratio at Tco (R) = 0.881

**Step 4:** Determine the DU and irrigation guidelines for previously designed basin when irrigating bare soil (ex: furrow in a level basin).

Copy the Design Analysis from [Design a Basin Irrigation](#), Step 2 and Paste it into the Operations World Folder. Name this analysis "Step 4". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

## Operations World Tab

Select:

I want to... Optimize an irrigation for a set Inflow Rate or DU.

! know... L, W, Q, Dreq

## System Geometry Tab

Length, L: 200 m

Width, W: 75 m

## Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select **0.04 - Bare Soil**

## Execution Tab:

Verify Dreq = 100 mm, L = 200 m, W = 75 m &amp; Q = 230 lps

Press Run Button

## Results Tab:

View under Operations Results:

DU = 87%

Cutoff Time (Tco) = 2.08 hr (125 min)

Advance Time = 1.76 hr (106 min)

Advance Distance at Tco = 200 m

Advance Distance Ratio at Tco (R) = 1

The example is WCL Report #19 stops here, however, using WinSRFR this example can be extended by simulating the irrigations from Steps 3 & 4 to verify the basin design & operations.

To continue this example, proceed to [Simulate a Basin Irrigation](#).

## 2.5 Simulate a Basin Irrigation

Simulate a Basin Irrigation is an extension to the **Chapter 4 - Example Design** from the WCL Report #19, ***BASIN - A Computer Program for the Design of Level-Basin Irrigation Systems - Version 2.0*** published by the USDA / ARS / US Water Conservation Laboratory in Phoenix, AZ.

You may open the WinSRFR file, **Basin Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

This example is continued from [Operate a Basin Irrigation](#).

**Simulation Objective:** Verify the irrigation operating conditions for the following basin field.

**Basin Dimensions:** 75 m wide by 200 m long

**Anticipated Cropping Pattern:** A variety of crops will be grown with alfalfa creating the most resistance to flow; thus, a Manning n of 0.15 would be selected for this condition. A Manning n of 0.04 is used for anticipated smooth conditions or level furrows used within the basins.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov exponent, a, of 0.5.

**Available Flow Rate to Basins:** 230 lps

**Step 5:** Simulate an irrigation for previously designed basin when growing alfalfa.

Copy the Design Analysis from [Operate a Basin Irrigation](#), Step 3 and Paste it into a new Simulation World Folder. Name this simulation "Step 5". Refer to [Cut / Copy Paste](#) for help.

Enter / verify field conditions and run criteria:

Simulation World Tab

Cross Section = Basin

Upstream Condition = No Drainback

Downstream Condition = Blocked End

System Geometry Tab

Slope, S: 0 m/m

Length, L: 200 m

Width, W: 75 m

Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select **0.15 - Alfalfa**

Execution Tab:

Press Run Button

Results Tab:

Compare results to those from Operations Analysis World.

**Step 6:** Simulate an irrigation for previously designed basin with bare soil (ex: furrow in a level-basin).

Copy the Design Analysis from [Operate a Basin Irrigation](#), Step 4 and Paste it into a the same Simulation World Folder. Name this simulation "Step 6". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

Simulation World Tab

Cross Section = Basin

Upstream Condition = No Drainback

Downstream Condition = Blocked End

System Geometry Tab

Slope, S: 0 m/m

Length, L: 200 m

Width, W: 75 m

Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select **0.04 - Bare Soil**

Execution Tab:

Press Run Button

Results Tab:

Compare results to those from Operations Analysis World.

## 2.6 Design a Border Field

Design a Border Field is similar to [Design a Basin Field](#), except the field has a slope so borders are required.

You may open the WinSRFR file, **Border Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

**Objective:** Determine the optimum border size for the following field and design conditions.

**Field Dimensions:** 600 m wide by 1200 m long

**Field Slope:** 0.0005 m/m

**Anticipated Cropping Pattern:** Alfalfa will be grown creating a resistance to flow represented by a Manning n of 0.15.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov a of 0.5.

**Available Flow Rate to Borders:** 230 lps

**AE:** 85%

**Step 1:** Determine the optimum length & width for a border within the field.

Create a new, default Design Analysis in a Design World Folder using either WinSRFR's Edit menu or the World Folder's right-click context menu. Name this analysis "Step 1".

Enter field conditions and run criteria:

Design World Tab

Cross Section = Border

Upstream Condition = No Drainback

Downstream Condition = Open End

Select:

I want to ... Given an Inflow Rate, find the tradeoffs between  
Border Length and Width.

Using... Depth Criteria: Low Quarter

System Geometry Tab:

Bottom Description: Slope

Slope, S: 0.0005 m/m

Soil / Crop Properties Tab

Roughness Method: NRCS Suggested Manning n

Select 0.15 - Alfalfa

Infiltration Method: Known Characteristic Infiltration Time

Char. Infiltration Depth: 100 mm

Corr. Infiltration Time: 3.5 hr (210 min)

Corr. Kostiakov a: 0.5

Inflow Management Tab:

Required Depth, Dreq: 100 mm

Inflow Rate, Q: 230 lps

Execution Tab:

Verify Width = TBD, Q = 230 lps & Dreq = 100 mm

Verify Depth Criteria is Low Quarter

Select Contour Ranges of:

Border Width: 10 to 300 m

Border Length: 50 to 600 m

Press Run Button

Results Tab:

Select the PAE lq tab toward the top of the window.

Note the highest PAE contour of 85% at the lower right of the graph.

Select the Design / Choose Solution... menu item to choose an optimum length & width. In this case choose:

Length: 400 m (field length of 1200 m is evenly divisible by 400)

Width: 40 m (field width of 600 m is evenly divisible by 40)

Press Ok.

A new tab containing the Solution Point for L=400m & W=40m is added to the Results.

Note the graph showing the infiltration distribution followed by the irrigation performance parameters.



## 2.7 Operate a Border Irrigation

Operate a Border Field is similar to [Operate a Basin Field](#), except the field has a slope so borders are required.

You may open the WinSRFR file, **Border Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

This example is continued from [Design a Border Field](#).

**Objective:** Find alternate Inflow Rates & Cutoff Times that will yield the desired Application Efficiency.

**Border Dimensions:** 40 m wide by 400 m long

**Border Slope:** 0.0005 m/m

**Anticipated Cropping Pattern:** Alfalfa will be grown creating a resistance to flow represented by a Manning n of 0.15.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov a of 0.5.

**Available Flow Rate to Borders:** TBD

**AE:** 85%

**Step 2:** Verify the irrigation results from Step 1

Copy the Design Analysis from Step 1 in [Design a Border Field](#) and Paste it into an Operations World Folder. Name this analysis "Step 2". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

Operations World Tab

Cross Section = Border

Upstream Condition = No Drainback

Downstream Condition = Open End

Select:

I want to ... Evaluate the operations of an irrigation.

Using ... Cutoff Criteria: Cutoff Time

Depth Criteria: Low Quarter

System Geometry Tab:

Bottom Description: Slope

Slope, S: 0.0005 m/m

Length, L: 400 m

Width, W: 40 m

Soil / Crop Properties Tab

Roughness Method: NRCS Suggested Manning n

Select 0.15 - Alfalfa

Infiltration Method: Known Characteristic Infiltration Time  
 Char. Infiltration Depth: 100 mm  
 Corr. Infiltration Time: 3.5 hr (210 min)  
 Corr. Kostiakov a: 0.5

**Inflow Management Tab:**

Required Depth, Dreq: 100 mm  
 Inflow Rate, Q: 230 lps  
 Cutoff Time, Tco: 2.22 hr

**Execution Tab:**

Verify Cutoff Criteria is Cutoff Time, Tco: 2.22 hr  
 Verify Length = 400 m, Width = 40 m, Q = 230 lps & Dreq = 100 mm  
 Verify Depth Criteria is Low Quarter

Press Run Button

**Results Tab:**

Only the Solution Point tab should be available.

Compare this graph with the one produced in Step 1. They should be nearly identical.

**Step 3:** Find Inflow Rates & Cutoff Locations that yield acceptable Application Efficiency.

Copy the Operations Analysis from Step 2 and Paste it into an Operations World Folder. Name this analysis "Step 3". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

**Operations World Tab**

Cross Section = Border  
 Upstream Condition = No Drainback  
 Downstream Condition = Open End

**Select:**

I want to ... Find the tradeoffs between Inflow Rate & Cutoff.  
 Using... Cutoff Criteria: Cutoff Time  
 Depth Criteria: Low Quarter

**System Geometry Tab:**

Bottom Description: Slope  
 Slope, S: 0.0005 m/m  
 Length, L: 400 m  
 Width, W: 40 m

**Soil / Crop Properties Tab**

Roughness Method: NRCS Suggested Manning n  
 Select 0.15 - Alfalfa

Infiltration Method: Known Characteristic Infiltration Time  
 Char. Infiltration Depth: 100 mm  
 Corr. Infiltration Time: 3.5 hr (210 min)  
 Corr. Kostiakov a: 0.5

**Inflow Management Tab:**

Required Depth, Dreq: 100 mm

Inflow Rate, Q: TBD

Cutoff Time, Tco: TBD

**Execution Tab:**

Verify Cutoff Criteria is Cutoff Location, R

Verify Length = 400 m, Width = 40 m

Verify Depth Criteria is Low Quarter

Select Contour Ranges of:

Inflow Rate: 100 to 500 lps

Cutoff Time: 1 to 3 hr

Press Run Button

**Results Tab:**

Select the PAE lq tab toward the top of the window.

Note the highest PAE contour of 85% at the top center of the graph.

Select the Operations / Choose Solution... menu item to choose an optimum inflow rate & cutoff time. In this example choose:

Inflow Rate: 350 lps

Cutoff Time: 1.5 hr

Press Ok.

A new tab containing the Solution Point for Inflow Rate 350 lps, Cutoff Location 0.65 is added to the Results.

Note the graph showing the infiltration distribution followed by the irrigation performance parameters.

## 2.8 Simulate a Border Irrigation

Simulate a Border Field is similar to [Simulate a Basin Field](#), except the field has a slope so borders are required.

You may open the WinSRFR file, **Border Examples.srfr**, installed under WinSRFR/Examples to view the results of each step in this example.

This example is continued from [Operate a Border Field](#).

**Objective:** Simulate the operating conditions for the following border field.

**Border Dimensions:** 40m wide by 400m long

**Anticipated Cropping Pattern:** Alfalfa will be grown creating a resistance to flow represented by a Manning n of 0.15.

**Soil Conditions:** For the given soil and crops to be grown, the design application depth, Dreq, is 100 mm which is characterized by an infiltration time of 210 minutes using a Kostiakov a of 0.5.

**Available Flow Rate to Borders:** 230 lps

**Design DU:** 80%

**Step 4:** Simulate an irrigation for previously designed border when growing alfalfa.

Copy the Operations Analysis from Step 3 in [Operate a Border Field](#) and Paste it into a Simulation World Folder. Name this analysis "Step 4". Refer to [Cut / Copy Paste](#) for help.

Enter field conditions and run criteria:

Simulation World Tab

Cross Section = Border

Upstream Condition = No Drainback

Downstream Condition = Open End

System Geometry Tab

Slope, S: 0 m/m

Length, L: 400 m

Width, W: 45 m

Soil / Crop Properties Tab:

Roughness Method: NRCS Suggested Manning n

Select 0.15 - Alfalfa

Infiltration Method: Known Characteristic Infiltration Time

Char. Infiltration Depth: 100 mm

Corr. Infiltration Time: 3.5 hr (210 min)

Corr. Kostiakov a: 0.5

Inflow Management Tab:

Required Depth, Dreq: 100 mm

Inflow Rate, Q: 350 lps

Cutoff Method: Time-Based Cutoff  
Cutoff Time, Tco 1.5 hr

Data Summary Tab  
Verify all values on one tab

Execution Tab:

Press Run Button

Results Tab:  
Compare results to those from Operations Analysis World.

### 3 Technical Background

The U.S. Water Conservation Lab (USWCL) has developed several software programs over the past 20+ years to aid in the efficient design, operation, management and simulation of surface irrigation. Included in this list are:

BASIN – Level-Basin irrigation design and management

BORDER – Sloping-Border irrigation design, management and operations

SRFR – Basin, Border and Furrow irrigation simulation

The newest software program, WinSRFR, combines the features and functions from these three legacy DOS programs while adding new capabilities like irrigation event analysis. Users of BASIN, BORDER & SRFR will notice many similarities in nomenclature, data groupings, selections and output displays. While the functionality provided by these older programs is still valid, WinSRFR moves this functionality into the modern Windows paradigm.

WinSRFR is produced by the Arid-Land Agricultural Research Center (ALARC), the successor to the USWCL. ALARC is part of the USDA's Agricultural Research Service (ARS).

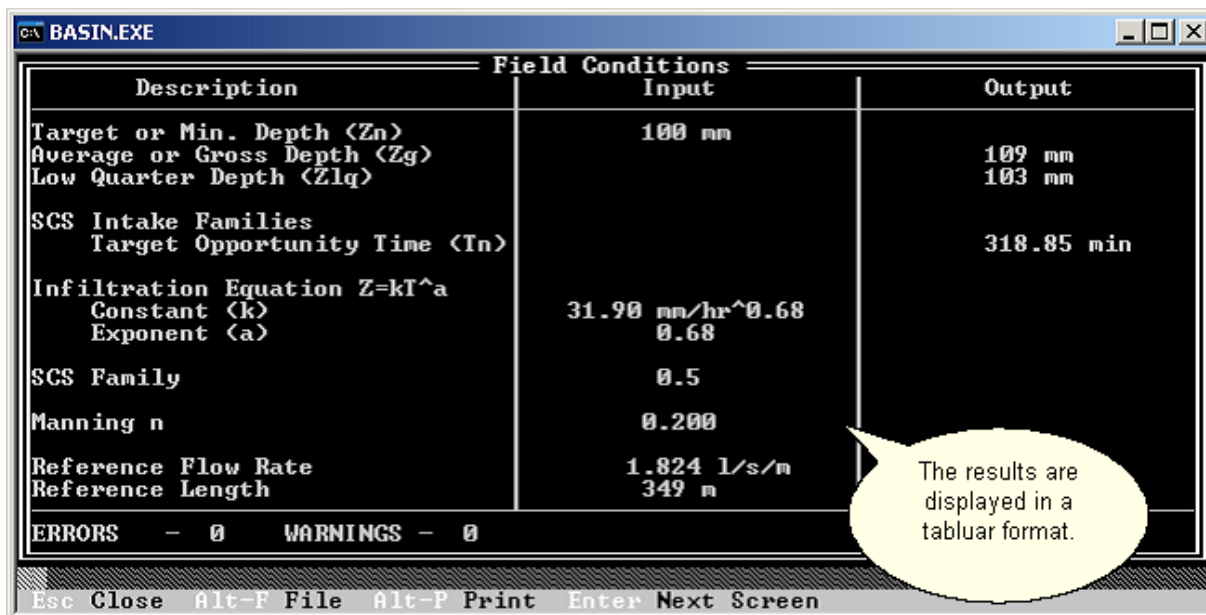
### 3.1 BASIN

BASIN is a menu-driven program for the design of level-basin irrigation systems where water is assumed to flow from one end to the other (one-dimensional). The user enters field conditions regarding soil infiltration and flow resistance. BASIN then allows the user to examine the relationships between field dimensions, inflow rate, and cutoff criteria (time or location of advance). One combination of these variables is displayed in an output table. The user can change inputs and rerun to compare alternatives. (The relationships presented in BASIN are derived from one-dimensional simulation results that were captured in tables in dimensionless form.)

The latest release, BASIN 2.0 - Patch 1, occurred on January 20, 2000.



The Calculate menu is used to execute the selected function; the results are then displayed in a text-based table.



Field Conditions		
Description	Input	Output
Target or Min. Depth (Zn)	100 mm	109 mm
Average or Gross Depth (Zg)		103 mm
Low Quarter Depth (Zlq)		
SCS Intake Families		
Target Opportunity Time (Tn)		318.85 min
Infiltration Equation $Z=kI^a$		
Constant (k)	31.90 mm/hr <sup>0.68</sup>	
Exponent (a)	0.68	
SCS Family	0.5	
Manning n	0.200	
Reference Flow Rate	1.824 l/s/m	
Reference Length	349 m	
ERRORS - 0	WARNINGS - 0	

Esc Close Alt-F File Alt-P Print Enter Next Screen

BASIN provides both physical design as well as operations and management support for level-basin surface irrigation. While not clearly delineated in the program, physical design functions result in the calculation of field Length and/or Width. Functions that do not produce one of these two physical parameters are considered to be operation and management functions. Operations and management functions are used to test and optimize irrigation parameters such as inflow rate, cutoff time or location and distribution uniformity.



## 3.2 BORDER

BORDER, a DOS program, pertains to plane, sloping-border strips with tailwater runoff. It is assumed that there is no transverse slope and that the inflow is distributed uniformly across the width and is constant with time until cutoff. BORDER consists essentially of a stored database of previously calculated irrigation simulations along with a mechanism for quickly retrieving these and displaying the results of any given set of geometrical-design and operating parameters. Such results can be expressed through selected performance indicators, such as application efficiency, distribution uniformity, adequacy of irrigation, water cost per application, etc.

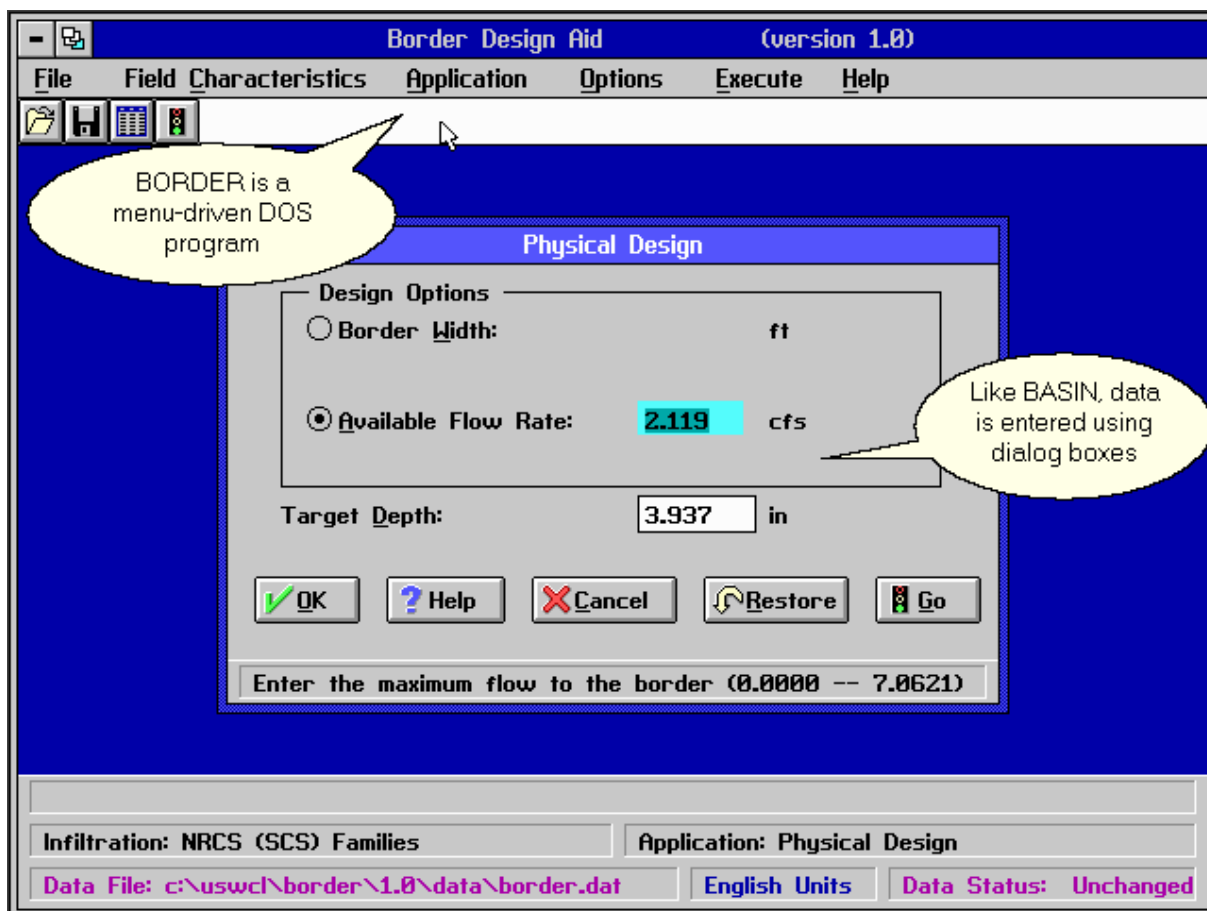
The design of sloping-border strips with tailwater runoff is facilitated by displaying the results of a whole range of design and operating parameters, so that a user can see what is possible in the way of performance with given field conditions, as well as what combinations of parameters yield an optimum. Values of selected performance indicators are calculated on a grid defined by the range of design or operating variables. Contour lines are then interpolated between grid values, to display the behavioral pattern of the chosen performance indicator as the design or operating parameters are varied.

When operated in physical design mode and the maximum available water supply to the field is known, BORDER can display the effect of varying border length and width on selected performance indicators; alternately the inter-relationship between inflow and length can be displayed for a given width.

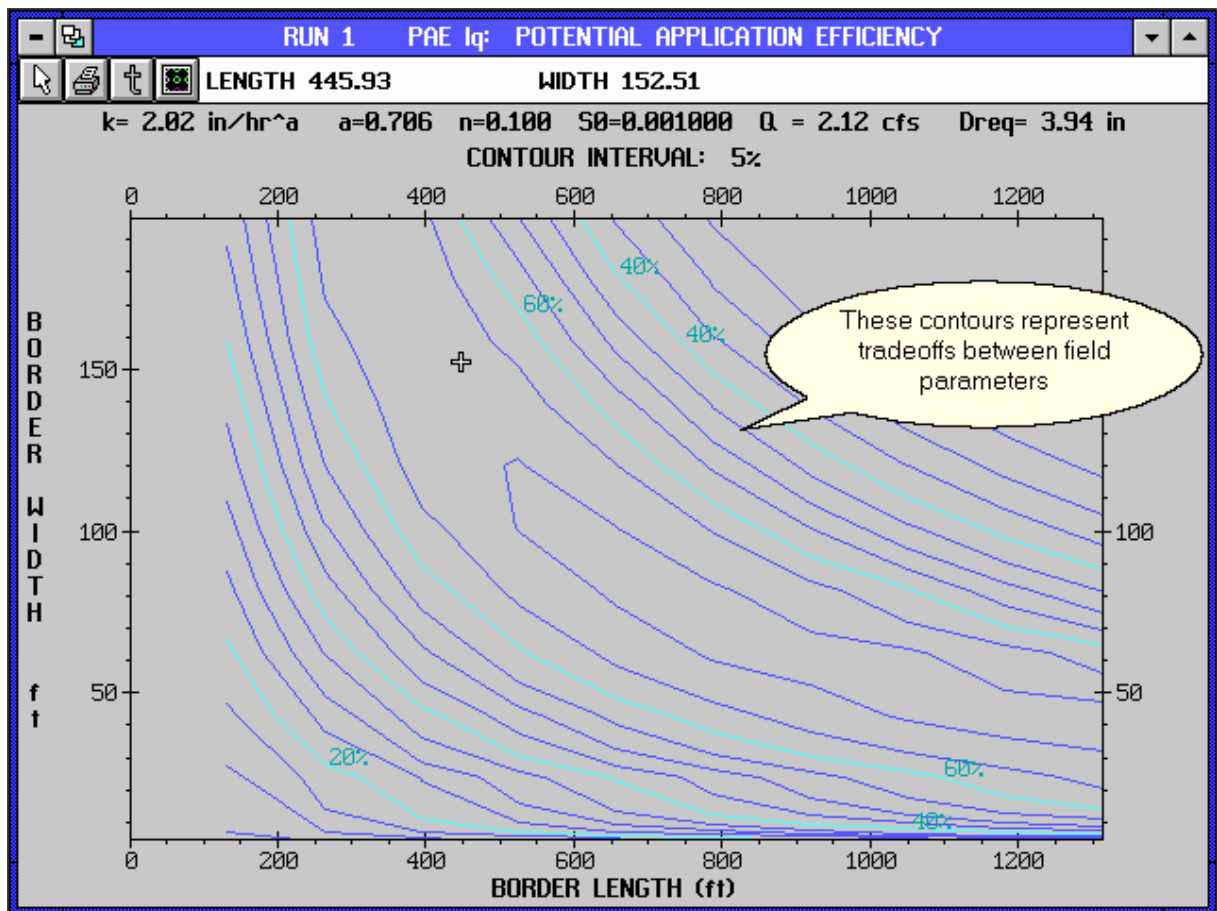
In management mode, the border-strip geometry is input and the effect of variations in inflow rate and cutoff time on selected performance indicators can be explored. As an alternative to cutoff time, the position of the advancing front in the border strip at cutoff can be displayed.

Finally, in irrigation-evaluation mode, with both physical geometry and operating conditions specified, all factors that determine irrigation performance are known, and BORDER displays the outcome.

The latest release, BORDER 1.0 - Update 2, occurred on January 31, 2000.

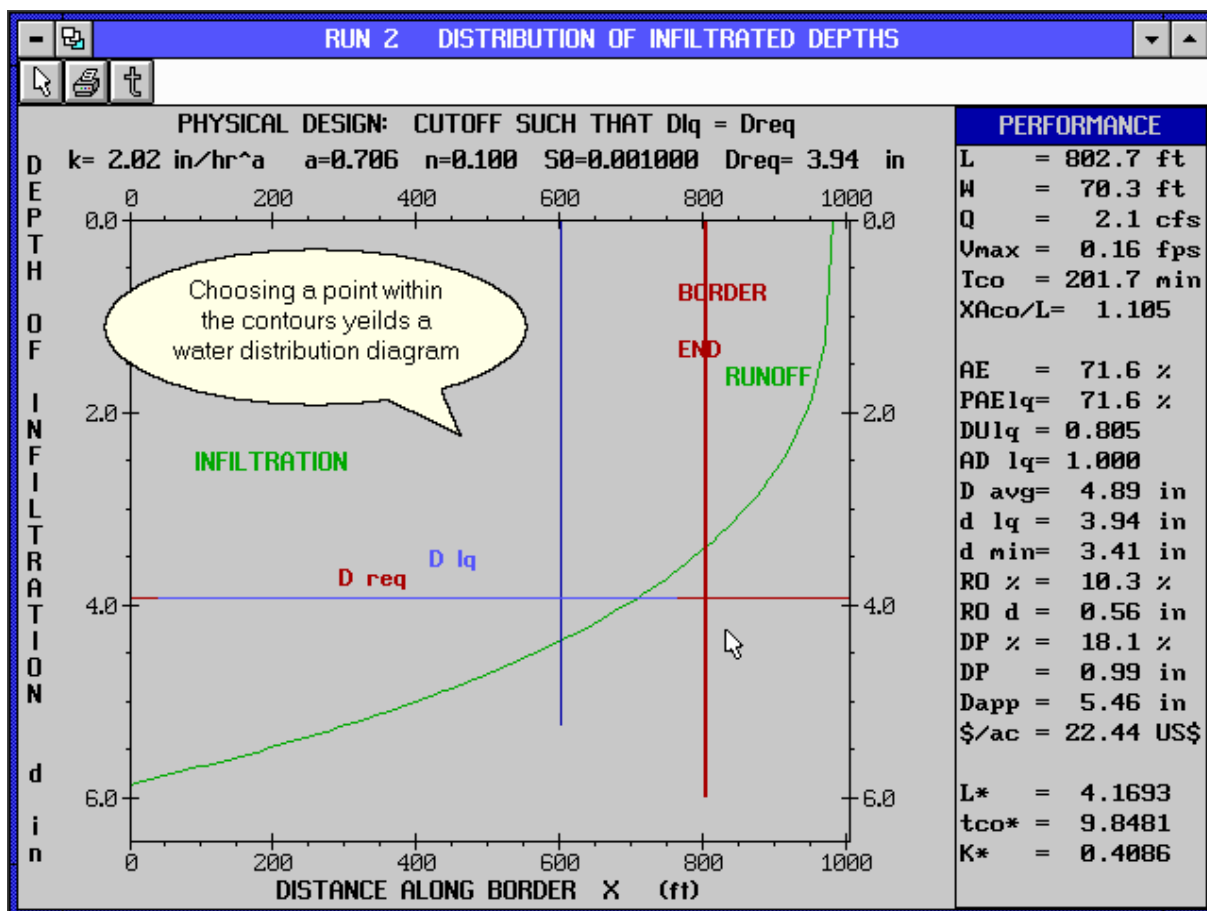


The Execute menu is used to run the selected function and the results are displayed as graphs, some with additional parameter lists.



The result of a BORDER run is a set of contours representing many possible solutions. In the example above, the contours show the tradeoff in the low-quarter Potential Application Efficiency (PAElq) for border lengths from 0 to 1300 feet and widths from 0 to 200 feet.

To get more information about a specific length and width, the user clicks within the contours to pick a single point to produce a water distribution diagram for that point. A resulting water distribution diagram is shown below.



This water distribution diagram graphs the depth of infiltration that occurred along the length of the border field. Shown on the right side is a set of performance parameters.

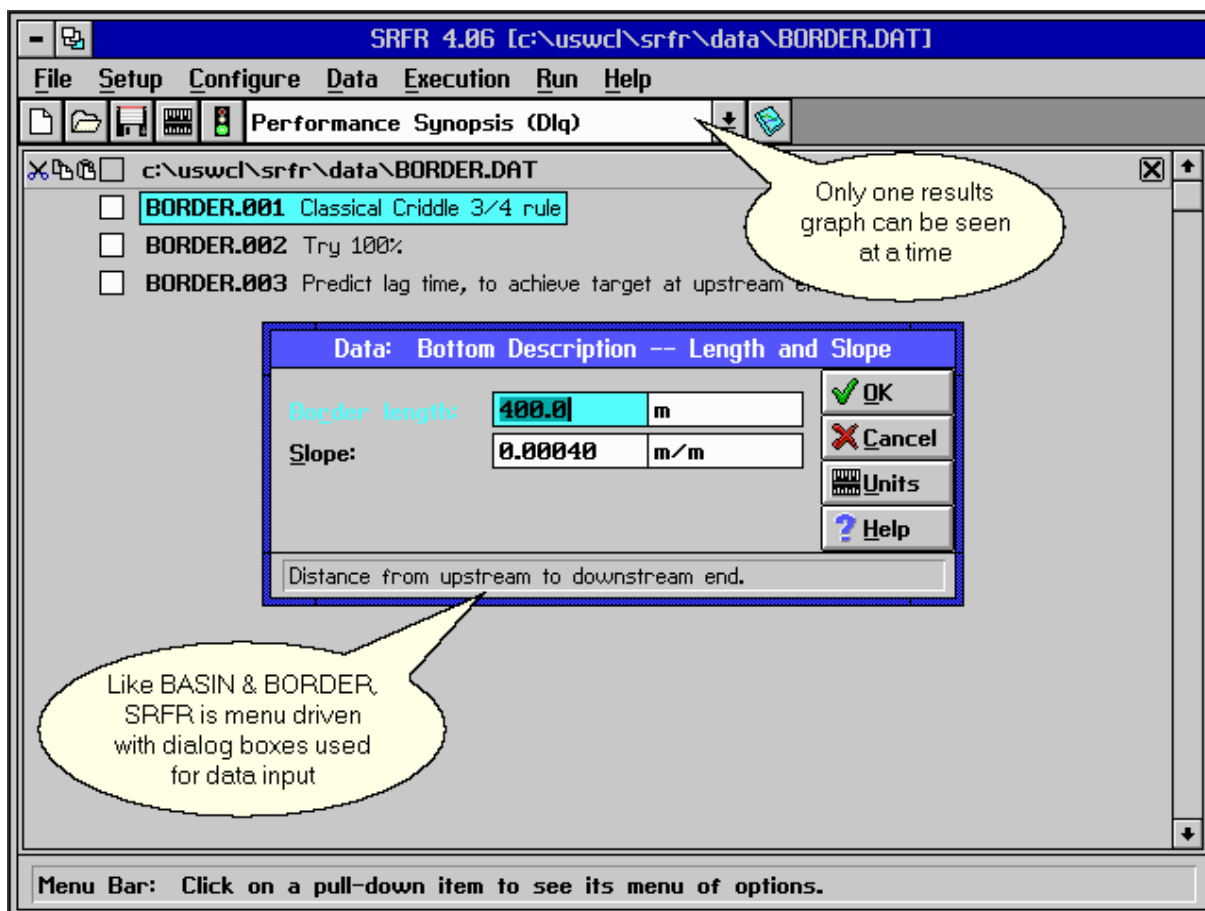
### 3.3 SRFR

SRFR, a DOS program, is a one-dimensional mathematical model for simulating surface irrigation -- in borders, basins, and furrows. It is assumed that all flow characteristics vary only with distance from the inlet and time. No variation transverse to the main direction of flow is considered. Thus, any cross slope in borders and basins is assumed negligible; also, the inflow therein is assumed distributed uniformly across the width. Only single furrows are considered; neighboring furrows are assumed to have identical flows --any variation in properties from furrow to furrow within a field must be modeled separately. On the other hand, field properties like the infiltration characteristics and roughness, bottom slopes, and furrow cross sections for example, can have a prescribed variation with distance along the bed, and even with inundation time.

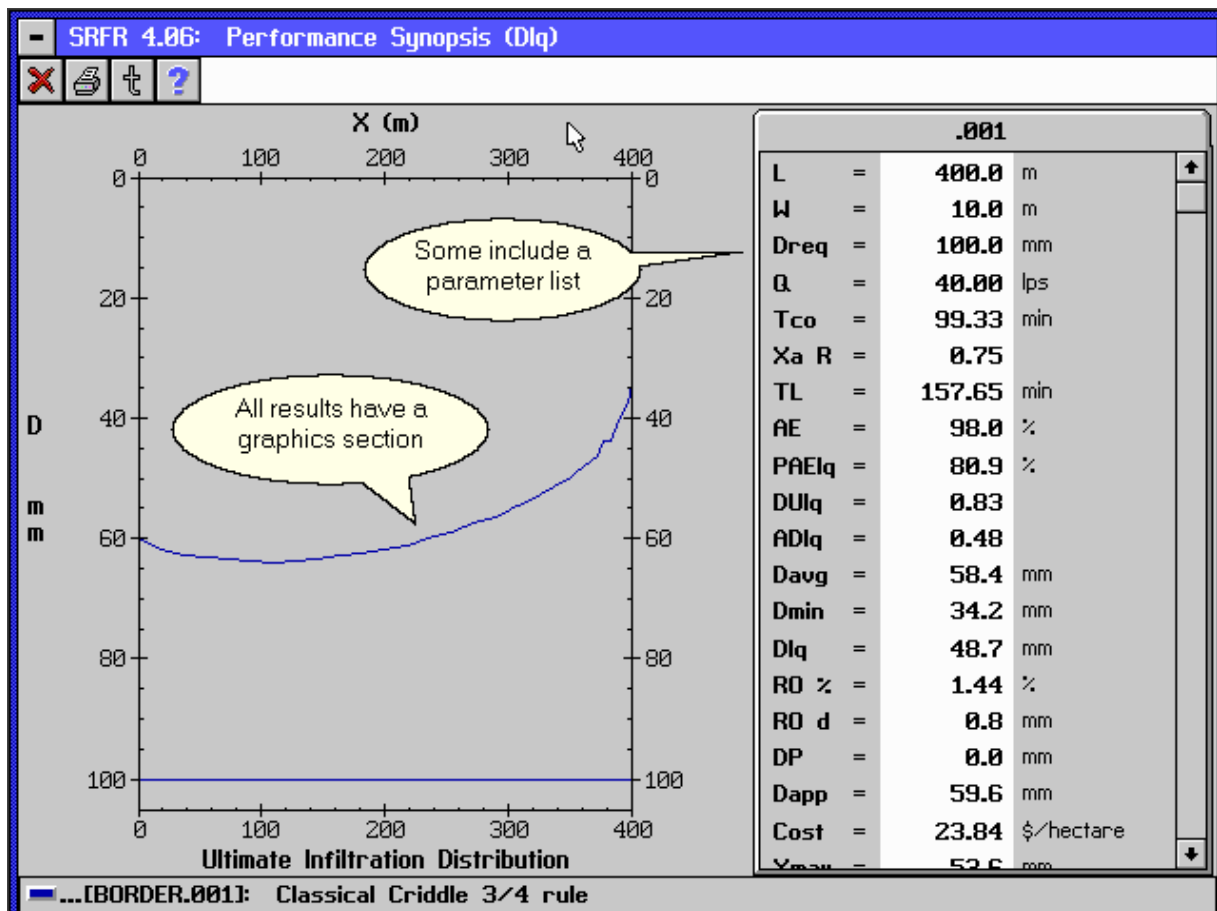
The results of a simulation, like those of an actual run in the field, depend on the hydraulic properties of the soil and crop (if the vegetation is immersed in the flow), the physical design of the system (length, slopes, etc.), and the irrigation management: flow rates, duration, etc., as well as the target depth of infiltration for the irrigation. When all of these quantities are prescribed by the user -- through the interactive data-entry windows -- the simulation can be performed. The results -- the advance and recession curves, the runoff, and the distribution of infiltration depths along the length of the run when recession is complete -- can be presented both graphically, and numerically through a series of performance indicators, such as application efficiency, distribution uniformity, adequacy of irrigation, water cost per application, etc. Moreover, the graphical results of several simulations under different conditions can be superimposed in different colors for convenient comparison. During the course of each simulation, an animated graphic of the soil and water surfaces and the growing infiltration profile in the soil are displayed.

Simulations consist of numerical solutions of equations which represent, mathematically, universal physical principles like conservation of mass and momentum. These general equations are complemented by user-given conditions of the irrigation to make a specific solution possible.

The latest release, SRFR 4.06, occurred on November 18, 1999.



The Run menu is used to execute the selected function and the results are displayed as graphs, some with additional parameter lists. An animation showing the surface water flow and infiltration is displayed while the simulation is running.



SRFR can produce graphs for several performance parameters one of which is the Performance Synopsis (DIq) shown above. This graph is similar to [BORDER](#)'s Distribution of Infiltrated Depths for PAElq graph shown in the previous section.

## 3.4 Manuals and Help

This section provides information from BASIN, BORDER & SRFR manuals and help systems that is pertinent to their inclusion within WinSRFR. Since WinSRFR incorporates the functionality from three legacy DOS programs, this information also applies to WinSRFR's users:

<u>BASIN</u>	Design & Operations of level-basin irrigations
<u>BORDER</u>	Design & Operations of sloping-border irrigations
<u>SRFR</u>	Simulation of basin, border & furrow irrigations

### 3.4.1 BASIN

The following text was edited from BASIN's manual and help system to make it compatible with WinSRFR's incorporation of BASIN's functionality.

#### BASIN - Overview

Needs to be added.

#### Field Conditions

When designing a basin-irrigation system, it is important to properly define the conditions of the field which are expected during irrigations. Since field conditions change over the season, it is recommended you design for acceptable performance over a range of conditions (e.g., to give appropriate seasonal performance). Thus far, BASIN only considers flat basins (no furrows or corrugations), and thus considers only crops planted "on the flat."

#### Infiltration

There are a variety of ways to describe infiltration. Basin design is based on the net or desired depth of infiltration,  $Z_n$ , however the design procedure also needs the time to infiltrate this depth,  $T_n$ , and the infiltration exponent  $a$ . Basin design was developed from a Kostiaikov power infiltration function, but the results are not very sensitive to the exact shape of the infiltration function (defined by  $a$ ) so approximations to any function can be made. Four options are provided specifying infiltration:

1. Known Target Infiltration Time
2. Infiltration Equation
3. SCS Infiltration Families
4. Time-Rated Intake Families (Merriam & Clemmens)

#### **Infiltration - Known Target Infiltration Time**

This is the basic option from which the design procedure was developed. The following data is requested:

**$Z_n$**  - Net depth to be infiltrated  
 **$T_n$**  - Time required to infiltrate  $Z_n$   
 **$a$**  - Exponent of Kostiaikov infiltration function

**$a$**  is the slope of cumulative infiltration depth-time curve on logarithmic paper. It defines how the infiltrated depth changes as the opportunity time changes. For design, the primary concern is the



range of infiltrated depths over the range of opportunity times within the basin.

### **Infiltration - Infiltration Equation**

Only a simple power infiltration equation can be used here:

$$Z_n = Z_o * T_n^a$$

where  $Z_o$  is that depth infiltrated in time  $T_o$ .

For example if  $T_o$  is 60 min., then  $Z_o$  is the depth infiltrated in 60 min. If  $T_o$  is the time base of an infiltration function, the  $Z_o$  will be the infiltration constant. The program calculates  $T_n$  from the above equation and the following input data:

$Z_n$  - Net depth to be infiltrated  
 $Z_o$  - Depth infiltrated in time  $T_o$   
 $T_o$  - Reference time  
 $a$  - Exponent of Kostiakov infiltration function

### **Infiltration - SCS Infiltration Families**

Under this option, the user selects from among the SCS intake families which are published in the SCS National Engineering Handbook, Border Irrigation (Chapter 4, Section 15, 1974). The program calculates the time required to infiltrate the net depth from the intake family equation. The value of  $a$  was approximated from a curve fit to the function between 2 and 4 inches. After selecting the infiltration family, the user need only select:

$Z_n$  - Net depth to be infiltrated

### **Infiltration - Time-Rated Intake Families (Merriam & Clemmens)**

It has been found that the SCS intake functions do not match field infiltration relations very well. Basically, the slope of the infiltrated depth-time relationship on logarithmic paper, or value of  $a$ , of the SCS families and real soils are often quite different. In addition, without field data, it has been difficult to estimate values of  $a$ . Merriam and Clemmens developed a relationship between the time to infiltrate 100 mm (3.94 in) and the value of  $a$ , which is a reasonable approximation for non-cracking soils (e.g.,  $a > 0.3$ ). The user then inputs:

$Z_n$  - Net depth to be infiltrated  
 $T_o$  - Time to infiltrate 100 mm

The program determines values for  $a$  and  $T_n$ . This is similar to the infiltration equation option (Option 2) with  $Z_o = 100$  mm. ("Time rated infiltrated depth families", 1985 ASCE Specialty Conference on Development and Management Aspects of Irrigation and Drainage Systems).

### **Resistance to Flow**

The roughness of the soil surface and the vegetation cause the water to move slower than if the water were moving over a smooth surface. Resistance to flow is defined by one of several relationships between the velocity of flow, the hydraulic radius (flow area over wetted perimeter), and the friction slope.

### **Resistance to Flow - Manning n**

The Manning resistance formula has been used frequently in surface irrigation studies because of its

simplicity. Several studies have indicated that the Manning n does not remain constant for flow through vegetation. For example, the Manning n for a long basin of alfalfa with a high unit flow rate would likely be higher than that for a short basin and a low unit flow rate. Some field experience with the performance of basins will help to provide more precise values.

Two options are given for entering values of Manning n. The user can chose to simply enter a value, or a selection can be made from a table of recommended values.

### User Entry of Manning n

The Manning resistance parameter can be entered within the range 0.02 to 0.5

### Table of recommended values for Manning n

The table is taken from USDA Soil Conservation Service recommendations for level basins and border strips (SCS National Engineering Handbook, Border Irrigation). An additional entry is provided based on field experience on long basins.

### Design

Three design methods are provided to design a basin:

1. Design based on application time (SCS approach)
2. Design based on advance distance at cutoff
3. Design based on maximum recommended length

BASIN assumes that water flows from one end of the basin to the other -- uniformly across its width. No adjustments are made to account for furrows, nor for conditions where the inflow is concentrated at a location along the "head" end (e.g., corner turnouts are not accounted for). From field experience, once the length is more than about twice the basin width, the location of the turnout appears to have little influence on the resulting advance and irrigation uniformity. For nearly square field, the diagonal distance has been used as the basin length, with the width determined by dividing the basin area by this diagonal length. BASIN does not make these adjustments for the user.

BASIN assumes the following relationship for design:

$$DU = (Z_n * L * W) / (Q_{in} * T_{co})$$

where

DU = distribution uniformity (minimum over average depth)

Z<sub>n</sub> = minimum depth infiltrated

L = basin length (parallel to direction of flow)

W = basin width (perpendicular to direction of flow)

Q<sub>in</sub> = basin inflow rate

T<sub>co</sub> = application time

If the minimum depth is equal to the required depth, DU is also the potential application efficiency (PAE) for full replacement (i.e., all infiltrated depth ÷ D<sub>req</sub>).

Additional output includes:

Advance Time Advance distance at time of cutoff (R)

Maximum flow depth

The design procedures also provide information on the low-quarter distribution uniformity (DUI<sub>q</sub>) and the low-quarter infiltrated depth (DI<sub>q</sub>), but these are not used in the design procedures. Since DU is always less than DUI<sub>q</sub>, design based on DU is always more conservative (i.e., predicts a lower uniformity).

### Design Based on Application Time (SCS Approach)

This design option closely matches the procedures developed by the Soil Conservation Service in their Border Irrigation National Engineering Handbook. However, their design charts are replaced with the solutions generated from BRDRFLW, providing more reasonable predictions of performance.

Under this option, the net depth (Z<sub>n</sub>) is always known, the application time (T<sub>co</sub>) and advance distance at cutoff (R) are always unknown. This leaves 4 parameters in the design process, 3 which must be specified and the other is solved for as the unknown. The choices are:

Known (Z <sub>n</sub> )	Unknown (T <sub>co</sub> , R)
-----	-----
Q, L, W	DU
DU, Q, L	W
DU, L, W	Q
DU, Q, W	L

The variables for General Design Criteria are:

DU - Distribution Uniformity  
 L - Basin Length  
 W - Basin Width  
 Q - Inflow Rate  
 Z<sub>n</sub> - Net Infiltration  
 R - Relative Advance at Cutoff  
 T<sub>co</sub> - Cutoff Time

### Design Based on Advance Distance at Cutoff

Field experience indicated that most irrigators use some measure of the advancing front to determine when to cut off the stream, rather than a predetermined application time or an accumulated volume. Wattenburger and Clyma have also suggested such an approach for design in developing countries where the inflow rate may be unknown. Here we use the relative advance distance at cutoff (R = advance distance at cutoff / field length) to determine the application time. For some choices of input variables, the minimum depth infiltrated becomes an unknown, subject to the specified cutoff criterion. Normally, Z<sub>n</sub> is assumed known as part of the field conditions. The choices are:

Known (R)	Unknown (T <sub>co</sub> )
-----	-----
DU, L, W	Z <sub>n</sub> , Q
DU, L, Q	Z <sub>n</sub> , W
DU, W, (Z <sub>n</sub> )	L, Q
DU, Q, (Z <sub>n</sub> )	L, W
L, W, (Z <sub>n</sub> )	DU, Q
L, Q, (Z <sub>n</sub> )	DU, W

The variables for Advance Distance Criteria design are:

DU - Distribution Uniformity  
 L - Basin Length  
 W - Basin Width  
 Q - Inflow Rate

Zn - Net Infiltration  
 R - Relative Advance at Cutoff  
 Tco - Cutoff Time

### Design Based on Maximum Recommended Length

Use of machinery for cultural practices suggests the use of long basin for machinery efficiency. Analysis of level basin design conditions indicated that for a given set of field conditions and desired DU, the field's length has some practical limit, beyond which increasing the unit flow rate has a limited influence on improving DU or allowing longer lengths. This limiting design is provided to allow the user to determine a maximum potential length for the basin. We recommend analysis with the other design options following identification of a maximum length. The choices are:

Known (Zn)	Unknown (Tco)
-----	-----
Q, L	DU, W
L, W	DU, Q
DU, Q	L, W
DU, W	L, Q

The variables for Maximum Limit Line Criteria design are:

DU - Distribution Uniformity  
 L - Basin Length  
 W - Basin Width  
 Q - Inflow Rate  
 Zn - Net Infiltration  
 Tco - Cutoff Time

### Operations

One operations method is provided to evaluate the performance of a basin irrigation:

1. Evaluation of an actual irrigation event

#### Evaluation of the Results of Operation with a Particular Design Choice

Once the design is made, this option is used to determine how the basin will perform, given the field dimensions, flow rate and operating rules. The operating rules define when the inflow is cut off -- based on time, or based on the advance distance.

This option is useful for examining the results of a design -- in terms of how it will perform over a range of infiltration and roughness conditions and under different flow rates. This would allow one to perform a sensitivity analysis.

### Terminology

#### **R - Relative Advance at Tco**

The relative advance distance at cutoff (R) is defined as the ratio of advance distance at cutoff to the field length. For user input, R is limited to the range 0.70 to 1.0. For non-cracking soils, this should cover the reasonable range of conditions. For cracking soils, smaller values of R are possible, but systems with such soils are not intended to be designed with BASIN.

#### **Basin Length (L) - English Units**

User input of basin length in the direction of flow is limited to 10 to 3281 ft.

**Basin Length (L) - Metric Units**

User input of basin length in the direction of flow is limited to 3.0 to 1000.0 m.

**Basin Width (W) - English Units**

User input of basin width perpendicular to the direction of flow is limited to 10 to 3281 ft.

**Basin Width (W) - Metric Units**

User input of basin width perpendicular to the direction of flow is limited to 3.0 to 1000.0 m.

**Basin Inflow Rate (Qin) - English Units**

The basin inflow rate is the discharge expressed as a volume per unit time. The following range of values is allowed as input: 0.1 to 50.0 cfs.

**Basin Inflow Rate (Qin) - Metric Units**

The basin inflow rate is the discharge expressed as a volume per unit time. The following range of values is allowed as input: 0.3 to 416.0 liters/sec.

**Time Required to Infiltrate Zn (Tn)**

Valid Times are defined as follows:  $12 \leq T_n \leq 2400.0$  minutes or  $0.2 \leq T_n \leq 40$  hours.

**Infiltration Exponent (a)**

The infiltration exponent is important in determining how the infiltrated depth varies over the range of infiltration opportunity times. For a small value of the exponent  $a$ , a given range of opportunity times will give a smaller range of infiltrated depths than will a large infiltration exponent. Under laboratory conditions with consolidated soils, the exponent  $a$  ranges between 0.5 and 1.0. However, under field conditions where soils are often unconsolidated, exhibit cracking, and for surface sealing layers, the exponent  $a$  can take on much smaller values. BASIN is not intended for soils that exhibit extreme cracking, such as some heavy clay soils. The allowable range of the exponent  $a$  within BASIN is 0.3 to 0.8.

**Net Depth Infiltrated (Zn) - English Units**

The net depth infiltrated as defined here is the desired or target depth to be infiltrated. It is also, the minimum depth infiltrated, as discussed under the design options. The net depth must be within the range  $1.0 \leq Z_n \leq 10.0$  inches.

**Net Depth Infiltrated (Zn) - Metric Units**

The net depth infiltrated as defined here is the desired or target depth to be infiltrated. It is also, the minimum depth infiltrated, as discussed under the design options. The net depth must be within the range  $25.4 \leq Z_n \leq 254$  mm.

**Infiltration Constant (k)**

If Infiltration is described by a power infiltration function (Kostiakov), then the user must specify an infiltration constant. This value of this constant depends on the units for both infiltration depth and time. It has units Length divided by Time to the exponent  $a$  [ $L \cdot (T^a)$ ]. One of three time units may be chosen; seconds, minutes, or hours. Because of the wide range of values which result from the choices of the time units and the exponent  $a$ , we do not explicitly limit the value of the infiltration constant. THE USER MUST ASSURE THAT THE VALUE ENTERED IS REASONABLE!

**Distribution Uniformity (DU)**

DU is defined as the minimum depth infiltrated divided by the average depth, expressed here as a percent. As user input, DU must be within the following range:  $20 \leq DU \leq 98$ . If the DU resulting from calculations falls outside this range, a warning message will be given since BASIN has no reliable way to estimate the true conditions. Future versions of BASIN will have DU low-quarter as a design choice in addition to DU.

### 3.4.2 BORDER

The following text was edited from BORDER's manual and help system to make it compatible with WinSRFR's incorporation of BORDER's functionality.

#### **BORDER -- Overview**

The BORDER design aid pertains to plane, sloping border strips with tailwater runoff. It is assumed that there is no transverse slope, that the inflow is distributed uniformly across the width and is constant with time until cutoff, that the soil and crop hydraulic roughness is satisfactorily described by the Manning formula with a single value of the Manning  $n$ , and that the infiltration characteristics of the soil are described by a power law in opportunity time (Kostiakov), with a single constant coefficient and exponent.

BORDER consists essentially of a stored database of previously calculated irrigation simulations along with a mechanism for quickly retrieving these and displaying the results of any given set of geometrical-design and operating parameters. Such results can be expressed through selected performance indicators, such as application efficiency, distribution uniformity, adequacy of irrigation, water cost per application, etc.

The design of sloping border strips with tailwater runoff is facilitated by displaying the results of a whole range of design and operating parameters, so that a user can see what is possible in the way of performance with given field conditions, as well as what combinations of parameters yield an optimum. Values of selected performance indicators are calculated on a grid defined by the range of design or operating variables. Contour lines are then interpolated between grid values, to display the behavioral pattern of the chosen performance indicator as the design or operating parameters are varied.

Field conditions -- slope, roughness, and soil infiltration characteristics are input to BORDER by the user, along with a target infiltration depth (volume per unit field area) satisfying the crop requirement.

With BORDER operated in physical-design mode, if the maximum available water supply to the field is known, BORDER can display the effect of varying border length and width on selected performance indicators; alternately the inter-relationship between inflow and length can be displayed for a given width. Note that physically, the pertinent factor in determining performance is the inflow per unit width; hence, the effect of changing inflow or width merely causes the displayed behavior pattern to shift vertically on the screen.

In operations mode, the border-strip geometry is input to BORDER, and the effect of variations in inflow rate and cutoff time on selected performance indicators can be explored. As an alternative to cutoff time, the position of the advancing front in the border strip at cutoff can be displayed. Finally, in irrigation-evaluation mode, with both physical geometry and operating conditions specified, all factors that determine irrigation performance are known, and BORDER displays the outcome.

The user can sequence through a series of potential field conditions, say, as infiltration or roughness varies over a season, or as the option of more frequent, lighter irrigations is explored in contrast to heavier, infrequent applications.

#### **Infiltration**

Four methods to enter the infiltration characteristics of the subject field are supported. In every case, however, the ultimate description is cumulative infiltration depth,  $d$  (volume per unit field area), as a power law in opportunity time  $t$  (Kostiakov equation),

$$d = k * t^a$$

in which  $k$  and  $a$  are constants. The coefficient  $k$  represents the depth infiltrated in a unit of time (e.g., hour or minute);  $a$ , the exponent, controls the reduction in infiltration rate with time. The smaller is  $a$ , the sharper the reduction in infiltration rate, and the more pronounced is the "dog leg" in a plot of cumulative infiltration vs. time. The theoretical value for uniform fine-grain sand in the early stages of infiltration is 0.5, increasing somewhat with time as the soil near the surface is saturated. Soils with a high clay content tend to exhibit smaller values.

On logarithmic paper, the plot of (Kostiakov) cumulative infiltration vs. time is always a straight line, with  $a$  representing the slope of the line, and  $k$  the intercept at 1 unit of time.

A particular approach to establishing  $k$  and  $a$  is chosen by selecting one of the following options.

1. Known Characteristic Infiltration Time
2. Infiltration Equation
3. NRCS (SCS) Families
4. Time Rated Intake Families

Soil infiltration characteristics are particularly important in their effect on irrigation performance, yet at the same time are often poorly known. In such a case, if the user can at least estimate the time the soil requires to infiltrate a depth of 100 mm (4 inches), the empirical relationship incorporated into the Time-Rated Intake Families can provide an estimate of the other characteristics. Similarly, the NRCS (SCS) families are based on an estimate of the long-term (basic) infiltration rate of the soil, and in some cases can provide reasonable figures.

#### **Infiltration Input -- Known Characteristic Infiltration Time**

A soil is often characterized by the time required to infiltrate a particular depth of water (volume per unit field area). This characteristic depth is typically the target application depth for the irrigation, but can be any convenient number. The next entry is the time to infiltrate that depth, with the time units specified by the user as hours or minutes. Finally, the exponent in the power law is entered.

Clearly, the only difference between entering infiltration data in this way rather than by the constants in the Kostiakov equation, is that the time intercept at a specified depth is entered, rather than the depth intercept  $k$  at unit time.

#### **Infiltration Input -- Infiltration Equation**

Inasmuch as the units of the Kostiakov coefficient  $k$  are depth per unit time-raised-to-the-power  $a$ , the numerical value of  $k$  depends strongly on the time units. Thus, the user selects first the unit time at which  $k$  constitutes the intercept in the graph of the Kostiakov equation. The numerical values of  $k$  &  $a$  are entered next.

#### **Infiltration Input -- NRCS (SCS) Intake Families**

In the 1970s, the Soil Conservation Service devised a system of characterizing soil infiltration by membership in a family. The name of the family, a decimal number, was related to the final (basic) infiltration rate (in inches per hour) exhibited by the soil after a long period of infiltration. Cumulative infiltration for each family was described by an expression of the form,

$$d = K * t^A + C$$

a plot of which on logarithmic paper exhibits a slight curve. Each family was defined by particular values of  $K$  and  $A$ ;  $C$  was the same for all members. In other words, every SCS family was characterized by a specific relation between  $K$  and  $A$ . All of the  $A$  values were somewhat higher than



0.5, and all families, if graphed, formed a regular progression of curves without intersections. While many soils fail to fit any of these families (graphs of their cumulative infiltration vs. opportunity time intersect many SCS families), some are, indeed, successfully incorporated within the SCS group. The opportunity to describe soil infiltration by SCS family is provided for those users whose experience justifies describing their subject soils in this way.

Since the Border Design Aid assumes Kostiakov infiltration, selection of an SCS family leads automatically to a best-fit pair of Kostiakov  $k$  and  $a$  to the SCS  $K$ ,  $A$ , and  $C$ . Thus, selection of an SCS family in this dialogue box fixes both  $k$  and  $a$ .

#### **Infiltration Input -- Time Rated Intake Families**

Merriam and Clemmens built upon the NRCS concept of a general relationship between the Kostiakov  $k$  and  $a$ , and, examining cumulative infiltration functions for many soils, empirically found a correlation between the exponent in the Kostiakov formula and the time to infiltrate a (characteristic) depth of, specifically, 100 mm (volume per unit field area).

The user specifies the time required to infiltrate 100mm (3.91 inches) in either minutes or hours. An empirical formula in BORDER, then, calculates the corresponding Kostiakov exponent,  $a$ , which is displayed, but cannot be changed independently; the corresponding Kostiakov  $k$  is automatically calculated.

#### **Resistance to Flow -- Manning $n$**

Both soil-surface drag and vegetative drag on the flowing irrigation stream are assumed to be characterized by a single value of the coefficient  $n$  in the Manning formula, independent of both flow rate and depth. For a given flow rate and bottom slope, a large value of  $n$  leads to a large flow depth, a small value to small depths. The Border Design Aid provides either User Entry of a numerical value of  $n$ , or a choice of USDA-NRCS recommended values based on crop conditions. Recent measurements indicate that the recommended values may be somewhat low.

#### **Resistance to Flow -- Manning $n$ -- User Entry**

Enter an estimate for the Manning coefficient accounting for both the condition of the soil surface and the nature of any crop growth in the border strip.

#### **Resistance to Flow -- Manning $n$ -- NRCS (SCS) Recommended Values**

Select one of the NRCS (SCS)-recommended values of the Manning coefficient on the basis of expected soil and crop conditions.

#### **Slope**

Enter the slope of the border bed, i.e., the drop in bottom elevation per unit length of border strip in the direction of flow. This number, which must be positive, is dimensionless: meters per meter in the metric system, feet per foot in the English system.

#### **Unit Water Cost**

This option prompts the user for a dollar value of irrigation water per unit volume, in order that the Border Design Aid can calculate an irrigation-water cost per unit field area.



## **Application**

Three modes of design assistance are provided by BORDER. Selection of one of these enables display of corresponding graphs:

### **Application -- Physical Design**

The aim of this option is to present the user with the effects of varying the physical-design variables over a range of values, to show both what is possible in the way of performance for the given soil, crop, and field conditions, and what values of design variables will yield that performance.

The physical-design variables are either (1) the length and width of the border strip, if a total available inflow is known, or (2) length and inflow rate if the latter is not given. In case (2), a border-strip width must be specified -- specification of a unit width will yield results on a per-unit-width basis. Thus, the user first selects the Design Option -- Border Width, or Available Flow Rate; the selection is completed by entering (editing) the numerical value of the selected variable. Since the variable actually governing performance is the inflow rate per unit width, changing inflow rate or width only shifts the entire set of contours vertically up or down on the screen.

Next, the Target Depth is selected, to be satisfied by either the minimum depth in the post-irrigation infiltration distribution, or the low-quarter average (that particular choice is deferred to the Execute, Options menu). In Physical-Design mode, BORDER seeks out and displays those combinations of the design variables which will satisfy the selected target depth. Also shown, as contours, are the resulting values of selected performance indicators.

The user will be asked to supplement the selected field conditions by a border width, or by a known total inflow rate. The results will be shown as contours of selected performance indicators on a field of physical-design variables (length and inflow rate, or length and width). Only those designs which just satisfy the target depth with the smallest values in the post-irrigation distribution of infiltrated depths are displayed.

### **Application -- Management**

With this option it is assumed that the physical layout of the border strip is known, i.e., not only the field infiltration, slope, and roughness, but also the length and width of the border strip. The aim is to present the user with the effects of varying the management variables -- target depth, inflow rate, and application time -- over a range of values, to show both what is possible in the way of performance, and what values will yield that performance.

Thus, selection of the Management option leads to a dialogue window with a prompt for border-strip length and width, to complement the field data entered under Field Characteristics. In addition, the user is also asked to choose between Cutoff Time and Advance-at-cutoff Ratio as the second management parameter, complementing inflow rate. Indeed, the application time can be specified either as the time at which inflow is cut off, or in terms of the position of the stream front in the border strip at the time of cutoff. The Advance-at-cutoff Ratio is the ratio of stream advance to border-strip length at the time of cutoff (values greater than unity are based on hypothetical advance beyond border end).

The results of varying the management parameters over specified ranges will be displayed as contours of performance indicators on a field of the two selected management variables.

The user complements the selected field conditions with border-strip dimensions. The results will be shown as contours of selected performance indicators on a field of management variables -- inflow rate and application time. In this mode, the smallest values in the infiltration distribution are independent of the user-selected target depth; the results, which assume the minimum or low-quarter depth just matches the target depth, show how performance is influenced by the target depth choice.

### **Application -- Operation Evaluation**

In this mode, BORDER accepts a complete set of field, physical-design, and irrigation-management parameters which, together, determine the outcome of an irrigation. The results are displayed as a graphic of the post-irrigation infiltration distribution along the length of the border strip, complemented by the numerical values of a set of performance indicators: application efficiency, distribution uniformity, irrigation adequacy, etc.

The application time can be specified either as the time to inflow cutoff, or in terms of the position of the stream front in the border strip at the time of cutoff. The Cutoff Advance Distance Ratio is the ratio of stream advance to border-strip length at the time of cutoff (values greater than unity are based on hypothetical advance beyond border end). Selection of one or the other criteria allows selection of a pertinent numerical value.

The Depth Criterion establishes whether the target depth is intended to be met by the minimum in the infiltration distribution, or the average of the low quarter.

With all parameters of the irrigation given, the results are quickly calculated and displayed as a graph of infiltration distribution along the length of the border strip and numerical values of an extensive series of performance indicators (application efficiency, distribution uniformity, runoff percentage, deep percolation, minimum or low-quarter depth, irrigation adequacy, cost per unit field area, etc.).

### **Solution-Grid Color Coding**

The Performance-Grid displays small circles amongst the performance contours to show the graphed locations of the computational pairs of design or management parameters. The color of the circle denotes the degree of success achieved in calculating the irrigation performance.

If no performance contours could be developed, a graph is displayed showing the grid at which solutions were attempted. At any given grid point, a solution can fail for any of several reasons. The type of failure is indicated by color coding the grid points. The significance of the colors follows:

- A green circle indicates a normal calculation
- Yellow indicates that, with the given length, the application (flow rate or cutoff time) is insufficient to yield a non-zero low-quarter-average, or minimum, depth in the infiltration distribution.
- Cyan indicates that solution requires an application time greater than the values in the database of border-irrigation simulations.
- Dark blue indicates a required application time smaller than database values.
- Magenta indicates an inflow rate larger than those contained in the database.
- Brown indicates an inflow rate smaller than those in the database.
- Red indicates a solution failure -- in which the succession of approximations failed to converge.
- Light grey indicates no solution is possible: either inflow, length, or application time are zero.

Tco\* grid, if selected, displays numerical values of dimensionless application time (cutoff time) at each of the computed performance-grid locations. The dimensionless database in BORDER is limited to the range 0.1 to 100.

K\* grid, if selected, displays numerical values of dimensionless infiltration (or dimensionless unit inflow rate) at each of the computed performance-grid locations. The dimensionless database for BORDER is limited to the range 0.1 to 10.0.

### **Depth criterion**

Allows the user to select the basis for satisfaction of the target depth-of-application by the irrigation, i.e., the basis for the numerical values of performance parameters: namely, either the minimum depth in the post-irrigation infiltration distribution, or the average of the low quarter of depths in that distribution.

### **Performance Contours**

The contours displayed describe the field of variation of a selected performance indicator (by default, named in the graph title; see Text, below) as it depends on the design variables. The contour interval is indicated below the graph title. The contours are drawn by interpolating between values of the performance indicator calculated on a grid of points. The grid can be made visible by selection of Performance Grid in the Border Options dialog box. The fineness of the grid mesh is also controlled in the Border Options dialog box. If the contour interval is too small relative to the grid spacing, the inadequate resolution can lead to erratic behavior of the contour lines. If portions of the field of contours appear inordinately jagged, the entire grid can be made finer through selection using the Border Options dialog box. Or, alternately, the grid can be made finer over just a portion of the field by dragging the mouse over that area (see Zoom, below). Of course, the Zoom feature can be used simply to increase or reduce the range of physical-design variables displayed.

### **Water Destination Diagram**

The complete irrigation results for a particular pair of physical-design parameters can be generated using right clicking on the point in the graph corresponding to the values of the parameters. Then select "Choose Solution at this point..." from the popup menu.

This display describes the performance of an irrigation, given a set of field conditions, a physical design, and irrigation-management parameters. Along with numerical values of a variety of performance parameters, the longitudinal distribution profile of water infiltrated into the border strip in the course of the irrigation is shown graphically (depth = volume per unit field area).

#### **For diagrams based on minimum depth:**

In the graphical field, the portion of the curve at the left, between the graph boundary, representing the upstream end of the border strip, and the double red lines labelled BORDER END constitutes the computed physical infiltration. The remainder of the green curve is hypothetical infiltration, beyond the actual end of the border strip. The area under this portion of the curve represents actual runoff from the border strip. The minimum depth in the distribution is shown by a horizontal blue line. The stated irrigation requirement is given by a red line.

#### **For diagrams based on low-quarter-average depth:**

In the graphical field, the portion of the curve at the left, between the graph boundary, representing the upstream end of the border strip, and the double red lines labelled BORDER END constitutes the computed physical infiltration. The remainder of the green curve is hypothetical infiltration, beyond the actual end of the border strip. The area under this portion of the curve represents actual runoff from the border strip. The average of the low quarter of depths in the distribution is shown by a horizontal blue line. The stated irrigation requirement is given by a red line. These two lines, of

course, are superimposed, for the conditions assumed in physical-design mode. The vertical blue lines represent the boundaries of the one-quarter of border length with the smallest depths in the distribution. Sometimes the lowest depths are at the downstream end of the border strip, sometimes at the upstream end, depending on specific conditions. And, sometimes, both ends contribute to the low-quarter average.

### Performance Parameters

The text below the Water Destination Diagram lists the values of performance parameters pertinent to the irrigation. Complementing the field conditions displayed at the top of the graph are the first six entries:

- **L** - Length
- **W** - Width
- **Q<sub>in</sub>** - Inflow Rate
- **V<sub>max</sub>** - Maximum stream-flow velocity (for erosion potential)
- **T<sub>co</sub>** - Cutoff Time
- **XACO/L** - The relative position of the stream front when the application ends (advance-at-cutoff ratio, the ratio between stream advance and border-strip length at cutoff; when the ratio is greater than unity, hypothetical advance, beyond border end, replaces physical advance).

These values are followed by the appropriate subset of these performance parameters:

- **AE** - Application Efficiency: volume infiltrated within the requirement divided by volume of inflow X 100%
- **PAE<sub>min</sub>** - Potential Application Efficiency (minimum): application efficiency if inflow is terminated at such time that the target depth is just satisfied by the minimum depth in the post-irrigation infiltration distribution -- exactly the conditions for Physical Design, so AE and PAE are equal.
- **PAE<sub>lq</sub>** - Potential Application Efficiency (low-quarter): application efficiency if inflow is terminated at such time that the target depth is just satisfied by the low-quarter-average depth in the post-irrigation infiltration distribution -- exactly the conditions for Physical Design, so AE and PAE are equal
- **DU<sub>min</sub>** - Distribution Uniformity (minimum): ratio of minimum depth of infiltration, to the average depth infiltrated
- **DU<sub>lq</sub>** - Distribution Uniformity (low-quarter): ratio of low-quarter-average depth of infiltration to the average depth infiltrated
- **AD<sub>min</sub>** - Adequacy (minimum): ratio of minimum depth to the desired, target depth of application
- **AD<sub>lq</sub>** - Adequacy (low-quarter): ratio of low-quarter-average depth to the desired, target depth of application
- **D<sub>inf</sub>** - Average Depth of Infiltration: volume infiltrated divided by border-strip area

- **Dmin** - Minimum Depth: minimum depth in the post-irrigation infiltration distribution
- **DI<sub>q</sub>** - Low-Quarter-Average Depth: average of the lowest quarter of depths in the post-irrigation infiltration distribution
- **RO %** - Runoff Percentage: ratio of volume of runoff to total volume of inflow X 100%
- **RO d** - Runoff Depth: volume of runoff divided by the area of the border strip
- **DP %** - Deep Percolation Percentage: ratio of volume of deep percolation to total volume of inflow X 100%
- **DP** - Deep Percolation: volume of infiltration beyond the requirement divided by the area of the border strip
- **Dapp** - Depth Applied: total volume applied (infiltration + runoff) divided by the area of the border strip
- **\$/ha or \$/acre** - Irrigation-water cost: cost in US dollars of irrigation water per unit area of cropped field

At the heart of the Border Design Aid is a dimensionless data base of inflow rates and cutoff times and their effect on performance (section 5.1 of manual -- BORDER, A Design and Management Aid for Sloping Border Irrigation Systems).

- **L\*** - Dimensionless Length: ratio of border length to reference length X R (eq. 4, section 5.1 of manual)
- **tco\*** - Dimensionless Cutoff Time: current value of dimensionless cutoff time
- **K\*** - Dimensionless Infiltration Coefficient: current value of dimensionless infiltration coefficient (whose inverse is dimensionless inflow)

### Zoom

It is possible to zoom in to a portion of the graph by dragging a rectangle with the mouse over the desired graph area -- from upper left to lower right.

Zooming out can be achieved by positioning the mouse cursor on a point within the graph and clicking the right mouse button. This leads to a grid expansion centered on the given point. Zooming closes the original graph, leaving only the zoomed version open.

### 3.4.3 SRFR

The following text was edited from SRFR's manual and help system to make it compatible with WinSRFR's incorporation of SRFR's functionality.

#### SRFR -- Overview

SRFR is a one-dimensional mathematical model for simulating surface irrigation -- in borders, basins, and furrows. It is assumed that all flow characteristics vary only with distance from the inlet and time.

No variation transverse to the main direction of flow is considered. Thus, any cross slope in borders and basins is assumed negligible; also, the inflow therein is assumed distributed uniformly across the width. Only single furrows are considered; neighboring furrows are assumed to have identical flows -- any variation in properties from furrow to furrow within a field must be modeled separately. On the other hand, field properties like the infiltration characteristics and roughness, bottom slopes, and furrow cross sections for example, can have a prescribed variation with distance along the bed, and even with inundation time.

The results of a simulation, like those of an actual run in the field, depend on the hydraulic properties of the soil and crop (if the vegetation is immersed in the flow), the physical design of the system (length, slopes, etc.), and the irrigation management: flow rates, duration, etc., as well as the target depth of infiltration for the irrigation. When all of these quantities are prescribed by the user -- through the interactive data-entry windows -- the simulation can be performed. The results -- the advance and recession curves, the runoff, and the distribution of infiltration depths along the length of the run when recession is complete -- can be presented both graphically, and numerically through a series of performance indicators, such as application efficiency, distribution uniformity, adequacy of irrigation, water cost per application, etc..

Moreover, the graphical results of several simulations under different conditions can be superimposed in different colors for convenient comparison. During the course of each simulation, an animated graphic of the soil and water surfaces, and the growing infiltration profile in the soil are displayed.

The simulations consist of numerical solutions of equations which represent, mathematically, universal physical principles like conservation of mass and momentum. These general equations are complemented by user-given conditions of the irrigation to make a specific solution possible.

### **Infiltration**

SRFR allows five different ways to enter the infiltration characteristics of the subject field. In every case, however, the ultimate description is cumulative infiltration depth,  $d$  (volume per unit area), based on a power law in opportunity time  $t$  (Kostiakov equation). This can be augmented by a constant,  $c$ , representing the essentially instantaneous intake upon initial contact of water with soil (as in cracking soils). Furthermore, a final, long-time infiltration rate,  $b$ , is recognized. Thus, a modified Kostiakov equation (or, alternately, a Branch Function, detailed below) is used to describe infiltration in SRFR:

$$d = k * t^a + b * t + c$$

in which  $k$ ,  $a$ ,  $b$ , and  $c$  are constants. The coefficient  $k$  represents the depth infiltrated in a unit of time (e.g., hour or minute);  $a$ , the exponent, controls the reduction in infiltration rate with time. The smaller is  $a$ , the sharper the reduction in infiltration rate, and the more pronounced is the "dog leg" in a plot of cumulative infiltration vs. time. The theoretical value for uniform fine-grain sand in the early stages of infiltration is 0.5, increasing somewhat with time as the soil near the surface is saturated. Soils with a high clay content tend to exhibit smaller values.

On logarithmic paper, the plot of (Kostiakov) cumulative infiltration vs. time is always a straight line, with  $a$  representing the slope of the line, and  $k$  the intercept at 1 unit of time (hour or minute: user selectable -- see Help: System of Units). A non-zero value of  $b$  causes the line to curve upwards, with increasing  $t$ , gradually approaching a slope of unity. A non-zero value of  $c$  causes the line slope gradually to decrease, at the smaller values of  $t$ , as cumulative infiltration approaches the constant value.

A further modification of the Kostiakov formula is provided by the Branch Function, suitable for many soils, which recognizes the final infiltration rate as taking over at the time at which the rate given by the original Kostiakov formula equals that final rate. Thus, infiltration depth is assumed to increase, initially, according to the relation:

$$d = k * t^a + c$$

and when the time rate,  $d/dt(d)$ , equals the specified final rate,  $b$ , infiltration continues indefinitely at the constant rate,  $b$ .

A particular approach to establishing the infiltration-formula constants is chosen by selecting one of the following options.

1. Time Rated Intake Families
2. Modified Kostiaikov formula
3. Branch Function
4. Known Characteristic Infiltration Time
5. SCS intake families

For a given soil, the numerical values of the infiltration-formula constants are heavily dependent on the assumption made for the effect of wetted perimeter on infiltration. Approximately, for a given soil, the Kostiaikov coefficients, except for the exponent  $a$ , are inversely proportional to the effective wetted perimeter. The default wetted perimeter for infiltration is the furrow spacing, except in the case that the SCS intake families are selected -- then it is the value given by the SCS empirical wetted perimeter formula.

Soil infiltration characteristics are particularly important in their effect on irrigation performance, yet at the same time are often poorly known. In such case, if the user can at least estimate the time the soil requires to infiltrate a depth of 100 mm (4 inches), the empirical relationship incorporated into the Time-Rated Intake Families (for non-cracking soils) can provide an estimate of the other characteristics.

In the 1970s, the Soil Conservation Service (now NRCS) devised a system of characterizing soil infiltration by membership in a group of families (USDA, 1974). The name of the family, a decimal number, was related to the final (basic) infiltration rate (in inches per hour) exhibited by the soil after a long period of infiltration. Cumulative infiltration for each family is described by an expression of the form,

$$d = k * t^a + c$$

a plot of which on logarithmic paper exhibits a slight curve. Each family is defined by particular values of  $K$  and  $A$ ;  $C$  is the same for all families. In other words, the SCS families are characterized by a specific relation between the name,  $K$ , and  $A$ . All of the  $A$  values are somewhat higher than 0.5, and all families, if graphed, form a regular progression of curves without intersections. While many soils fail to fit any of the families (graphs of their cumulative infiltration vs. opportunity time intersect many SCS-families), some are, indeed, successfully incorporated within the SCS group. The opportunity to describe soil infiltration is provided for those users whose experience justifies describing their subject soils in this way.

When entering field infiltration data for furrow flow, the user should take care to note the selected assumption for wetted perimeter for infiltration, because this selection materially affects the appropriate value of accumulated depth. The wetted perimeter for infiltration is multiplied by the time rate of increase of cumulative depth to yield the time rate of increase of accumulated volume per unit length of furrow. For a given physical furrow infiltration, a volume per unit length, the wetted perimeter for infiltration and the depth of infiltration are inversely proportional.

The default wetted perimeter for infiltration is the furrow spacing (unless an SCS Intake family has been selected to characterize soil infiltration).

### **Infiltration -- Time Rated Intake Families**



The user enters the limiting depth of infiltration, if any. This might be caused by an underlying layer of clay or hardpan. If infiltration is not limited, 0.0 is entered.

With time-rated intake families, the single entry, the time to infiltrate 100 mm (4 inches), defines the infiltration characteristics of the soil. The result is a Kostiakov formulation in the form  $k t^a$ , with the exponent  $a$  empirically tied to the characteristic time entered, and hence not independently selectable.

#### **Infiltration -- Modified Kostiakov Formula: $k * t^a + b * t + c$**

The four parameters of the formula are entered. Inasmuch as the units of the Kostiakov coefficient  $k$  are depth per unit time-raised-to-the-power- $a$ , the numerical value of  $k$  depends strongly on the time units. Thus, the user first selects the unit time (hour, minute) at which  $k$  constitutes the intercept in the graph of the Kostiakov equation, and then enters  $k$ .

The user then enters the limiting depth of infiltration, if any. This might be caused by an underlying layer of clay or hardpan. If infiltration is not limited, 0.0 is entered.

#### **Infiltration -- SCS Intake Families**

The user enters the limiting depth of infiltration, if any. This might be caused by an underlying layer of clay or hardpan. If infiltration is not limited, 0.0 is entered.

The user enters the family name for the SCS intake family thought to best represent the infiltration characteristics of the soil. Selection of this infiltration-specification option implies also (by default) a corresponding wetted perimeter for infiltration given by the SCS empirical formula.

The SCS intake formula has the form  $z = k t^a + c$ , in which  $k$  and  $a$  depend on the family number in accord with a published table, and  $c$  is a small constant (0.275 inches, or 7 mm), intended to make a better fit to field data. At low flows on very large slopes, the depth of flow can be of the same order of magnitude as this constant, and even smaller. This implies an enormous infiltration to the advancing flow, leading to a spasmodic simulated advance. This artificial problem is avoided if the pertinent SCS family is approximated by a best fit Kostiakov formulation,  $k * t^a$ . This option is selectable (and is the default) upon selection of the SCS families for characterizing infiltration.

The default wetted perimeter for infiltration characterized by an SCS intake family is the SCS empirical wetted perimeter, generally somewhat larger than the actual wetted perimeter of the furrow (for other characterizations of infiltration, the default wetted perimeter for infiltration is the furrow spacing).

### **Wetted Perimeter**

These options are available only at the Advanced Level.

Five assumptions on the effect of wetted perimeter on furrow infiltration are available in SRFR. It is essential to recognize that the coefficient values in the infiltration formulas are dependent, sometimes heavily so, on the assumption made here. Approximately, for a given soil, the Kostiakov coefficients, except for the exponent  $a$ , are inversely proportional to the effective wetted perimeter.

Local wetted perimeter means that the increase in volume infiltrated per unit length in a time step is given by the increase in depth multiplied by the current wetted perimeter.

The second choice multiplies the depth increase by the wetted perimeter at the upstream end.

Alternately, the wetted perimeter calculated from normal depth at the inflow end of the furrow is used.



A very simple assumption, particularly appropriate with cracking soils, is for the nominal wetted perimeter for infiltration to be the furrow spacing.

The SCS intake families were developed for furrow irrigation with an empirical wetted perimeter in mind. This wetted-perimeter function is the default option for the selection of the SCS families in the previous window, but the Advanced user can change this to any of the above to study the effect of this assumption.

### **Resistance to Flow -- Manning n**

Both soil-surface drag and the drag of inundated vegetation on the flowing irrigation stream are assumed to be characterized by a single value of the coefficient  $n$  in the Manning formula, independent of both flow rate and depth. For a given flow rate and bottom slope, a large value of  $n$  leads to a large flow depth, a small value to small depths.

The standard user can select either to supply a numerical value for the Manning  $n$ , or accept the values suggested by the SCS for a number of soil and crop conditions. Recent measurements suggest that the SCS recommended values may be somewhat low.

#### **Roughness -- Manning n**

Enter a value for the Manning  $n$ .

#### **Roughness -- SCS Suggested Manning n**

Recent measurements suggest that the SCS recommended values may be somewhat low.

Enter your selection of SCS recommended value.

#### **These options are available only at the Advanced level:**

If appropriate field data are available, the Manning  $n$  value can itself be allowed to vary as a power law of water depth -- to reflect the formula's inherent unsuitability for shallow flows with large roughness elements. Thus, if no variation with depth is assumed, the coefficient  $C_n$  is the constant value of the Manning  $n$ ; otherwise,  $C_n$  is the coefficient and  $A_n$  the exponent in a power-law relationship.

An alternative resistance formula, more physically based than the purely empirical Manning formula, is the logarithmic Sayre-Albertson relationship, similar in its origins and form to the Colebrook-White expressions for pipe flow. Here the absolute roughness of the soil surface is given by the variable,  $\chi$ , measured in units of length. Despite its theoretical advantages, typical field values of  $\chi$  are not generally known.

Submerged vegetation plays a role in resistance to water flow quite different from that of the soil surface. While the latter exerts shear only at the flow boundaries, vegetation exerts a form drag over the entire depth of submergence, depending heavily on the density of growth -- measured as frontal cross-sectional area per unit plan area of the flow channel (typically a border strip, or basin) per unit depth. The units of vegetative density are  $L^{-1}$ . Evaluation of vegetative drag, which can be substantially greater than the drag of the soil surface, is still in an experimental stage. For example, in a laboratory setting, with artificial vegetation in the form of vertical wires of diameter  $D$  uniformly spaced on a grid with  $N$  wires per unit floor area of a flume, the vegetative density is  $ND$ . In the field, it is still common practice to lump the two components of drag, surface and vegetative, together and express the result through a constant value of the Manning  $n$ , ignoring the form-drag characteristics of submerged vegetation altogether.

**Roughness -- Manning N Advanced, Vegetative Drag**

The fundamental unsuitability of the Manning formula for shallow flow in channels of high roughness has suggested allowing the Manning  $n$  to vary with depth, specifically as a power law in depth.  $C_n$  represents the coefficient in this power law, i.e., Manning  $n$  at unit depth, while  $A_n$  is the exponent in the power law. If there is no variation in Manning  $n$  with depth,  $C_n$  is the constant  $n$  value, and  $A_n=0$ .

Also enter the vegetative density, assumed independent of depth

**Roughness -- Sayre-Albertson Chi, Vegetative Drag**

The Sayre-Albertson chi, possessing units of length, is a measure of absolute roughness of the flow channel. It is essentially an indicator of the height of the roughness elements, but is influenced by the micro-geometry: element shape, size distribution, spacing density, etc. The Sayre and Albertson logarithmic formula for hydraulic drag, in general, follows drag variations with depth more closely than the Manning formula, but its structure does not permit the hydraulic radius of flow to be less than chi. In fact, at a hydraulic radius equal to chi, the calculated drag is infinite.

Any distance or time variation in the Sayre and Albertson chi value is entered in a table, constructed by the user in the data window by inserting lines as necessary. The + button in the table brings up time levels at which parameters are to be defined.

Vegetative density is expressed in area of vegetation facing the flow, per unit plan area, per unit depth. It is assumed independent of depth. Drag per unit length of flow is calculated from the estimated form drag of the vegetation.

**Inflow Management**

Allowable inflow-time patterns are the standard, consisting of a single pulse of given rate and duration, but allowing for cutback and a table of flow rate vs. time.

**Inflow Management -- Standard Hydrograph**

The time component of the inflow hydrograph can be specified either in terms of so many hours or minutes from the start of the irrigation, or in terms of the location of the stream front, when a change in flow rate (either a cutback or cutoff) is to be initiated.

Cutoff based on distance can depend in various ways on the stream behavior. This matter can be explored in the screen activated by pressing More, available only to the advanced user.

These options are available only at the Advanced level:

Downstream control of inflow depends upon the advance of the irrigation stream down the field. Inflow can be cut off when the stream reaches a given point down the length of run, or when a given infiltration depth has accumulated there, or when the point has experienced a given infiltration-opportunity time.

Upstream control, available only in sloping border strips, is designed to cut off the inflow at such time that the target depth is infiltrated at the upstream end just as recession begins there. The prediction of lag time necessary to specify such cutoff is performed by internal software interpolating within a dimensionless database of previously run simulations.

**System Geometry**

The choices reflect the allowable variations in system geometry with distance down the length of run.

The selection of furrow cross-section description or border or basin irrigation is made here. The (symmetrical) furrow cross section can be assumed approximated either by a trapezoid or by a power law in which the water-stream top width is assumed to vary in proportion to water depth raised to some exponent.

A Border Strip can have either an open end or a blocked end. Open End means free fall into a drainage ditch; Blocked End means no runoff whatsoever. Flat-planted Basins are not furrowed, are blocked at the downstream end, and can be set to any slope. They are equivalent to closed-end border strips.

Drainback into the supply ditch is enabled by checking this box in the Upstream boundary condition. Backflow begins when the water level in the supply ditch drops below the upstream surface elevation of the irrigation stream. Drainback, with its negative inflow after cutoff, allows higher efficiencies and greater control in basin irrigation, particularly with small target depths of infiltration, than simply cutoff to zero inflow. This option is allowed only with the standard or tabulated inflow hydrographs, and with the Zero-Inertia simulation mode.

Specification of the longitudinal bottom configuration can be made either in terms of bottom slopes or a table of distance vs. elevation.

### **Simulation Control**

The advanced user can select a basis for simulation.

The Saint Venant equations contain all the acceleration terms in an unsteady open channel flow; these are typically very small in surface-irrigation flows.

The Zero-Inertia model deletes the acceleration terms to provide a more robust simulation. This is tantamount to assuming that the forces stemming from depth variations with distance, bottom slope, and hydraulic drag are in equilibrium. Comparisons with solutions to the Saint Venant equations show that this assumption is adequate in surface irrigation.

As the slope of the flow channel increases, the zero-inertia formulation becomes increasingly difficult to apply, requiring subdivision of the advancing-stream length into many small cells, especially at the downstream end, where depth increases very rapidly with distance back from the front. These computational difficulties are avoided by utilizing the Kinematic-Wave mode of solution.

For steep slopes, the contribution of the depth gradient to the force balance is very small and can be neglected, leaving equilibrium between the force of gravity downslope and the hydraulic drag upslope. This is the basic premise of the normal-depth kinematic wave.

The default transition between zero-inertia and kinematic-wave formulations lies at a bottom slope of 0.001.

### **Simulation Control -- Cell Density**

Cell density influences the number of cells into which the stream is divided for the numerical simulation. Furthermore, the smaller the cell size, the smaller is the initial time step. The time step typically grows with time, depending on the behavior of the simulation, while the cell sizes are fixed with time.

A coarse grid selects 1/5 of the length of run for the initial cell size; medium, 1/10; fine (a typical default), 1/20; and extra fine, 1/40. Smaller cells are accommodated by entry of numbers greater than

40, following selection of Numerical Entry.

### Simulation Control -- Numeric

This experimental group of parameters are available only to users at the program-developer level. They should not be changed without consultation with the Arid-Land Agricultural Research Center, Maricopa, Arizona, as modifications can result in unexpected simulation behavior.

The most physically based parameter is YTREC, a water depth below which recession is assumed to occur. While depths within the computational boundaries can be less than YTREC, recession time for a point is determined by the time its depth crosses YTREC. YTREC is defaulted to 1/2 millimeter (see sample data file, DUNKLIN, for effect of various YTREC when infiltration is negligible -- stopped by an impenetrable layer beneath the soil surface).

NYUBC is the number of time steps over which the drop in inflow water depth to zero is assumed to occur in drainback operation of a basin upon cutoff (S 1360).

NIWAIT is the number of times that the Newton-Raphson correction vector is allowed to be shortened to forestall premature recession.

IT40 is a flag pertinent to selection of cutoff when a given depth has infiltrated at a given point along the length of run. If IT40 is set to 1, cutoff is initiated, instead, when the low-quarter average of infiltrated depth equals the given value.

RDFCT, defaulted in shell to 0.0, and in engine (I1.FOR) to 1.0; used in SA 6020+: if I=IPTQBK-1, RCMAX=RCMAX\*RDFCT, RMMAX=RMMAX\*RDFCT.

NDXKG is the minimum number of cells between KG (S 1350). Defaulted in shell to 0, in engine, to 1.

VDB1 is used in subroutine VOLUME\_BASED\_DT (666):  $VQ\_KRB(1)=VDB1*DELTA\_VZ\_KRB$ . Any shell value less than 1.0 is changed to 1.0 in the engine.

DTLRAT is the fraction of field length constituting the minimum allowable advance increment (S 100-). Shell default is 0.5; this (or any value .LE. 0.0) leads to engine value of 0.005

QCOAVG, Auto RDT (group3autoRDTChange in DATA.FI), IDT (group3IDTChangeMax in DATA.FI) not used (SRFR 4.06)

### Simulation Control -- Solution

The advanced user can override the default values for certain parameters of the numerical solution.

The simulation runs in dimensionless mode: physical variables are divided by reference variables with the same dimensions to yield dimensionless counterparts. Two systems are available in SRFR. One, based on normal depth at the given inflow in the given flow channel, is only possible in sloping channels and is the default for sloping channels. The other, based on a reference time (equal to cutoff time, if that is known), is the necessary default for horizontal channels, or those with adverse slope.

RDTSTG is the rate at which the solution time step is intended to increase, if and when the irrigation stream forms an essentially stagnant pool (SA 4440) (default: 1.2).

R0 (timeStepCtrlR0) is the dimensionless first guess for depth at the end of the first time step of advance. Any value set here < 0.05, will revert back to 0.1 in the engine.

R1 (iterationCtrlR1) is not in currently in use (SRFR 4.06).

FILFT is the weighting coefficient for left-side cell values in determining an average. Right-side values are multiplied by (1-FILFT). In zero-inertia and St. Venent modes, FILFT defaults to 0.5, while in KW mode, the default is 0.0.

STOPI is the maximum number of time steps to be run in the simulation. An upper limit has not been established; the default is 1451.

TSTOP is, similarly, an upper time limit on the simulated irrigation. The default is one week.

RCMXR and RMMXR control the tolerance to which the conservation-of-mass and conservation-of-momentum equations must be satisfied to complete a time step. These are both decimal fractions of the sum of the absolute values of the terms in the equations.

If the number of iterations required to satisfy the tolerances exceeds JHI (default: 7), the subsequent time-step sizes will be decreased.

If they fall below JLO (default: 6), the time step will be increased.

JMAX is the number of iterations allowed for convergence before corrective action is taken (default: 20).

JCOUNTMAX is the total number of iterations allowed in one time step (default: 60).

### **Simulation Control - Diagnostics**

For troubleshooting, the SRFR simulation engine writes diagnostic information of various types to the file SRFR.DGN housed in the subdirectory, DIAGNSTC, a child of the one containing the SRFR program files. To strike a balance between utility and ponderousness, the user should select judiciously the type of information written. The file can easily grow in size to tens of megabytes.

Additional "diagnostic" flags are made available for experimental transmission of Soil Erosion/Transport information to SRFR.

### **Simulation Control - Graphics**

This window controls the appearance of the animated surface-water and infiltrated-depth profiles generated in the course of the simulation. It also enables recording hydrographs and stream profiles during the simulation.

The first choice, Profile Forms, determines whether elevations or depths are plotted. Selection is made by scrolling with the arrow and clicking on the desired option. Elevation plotting identifies a sloping soil surface, at the bottom of a furrow or in a basin or border strip. Surface-water flow depths are shown above that line, to the same scale as the soil-surface elevations, and depths of infiltration are shown below it.

In steep slopes, the change in bottom elevation over the length of run dwarfs the surface-water depths, and the profile of the surface stream becomes barely visible. To discern its configuration (and the behavior of the simulation), it is necessary to plot depths, instead of elevations. The sloping soil surface, then, is not shown sloping, and the surface-water flow depths occupy a significant portion of the screen. The disadvantage to this kind of plot is that behind any obstruction in the flow channel (say a blocked end), flow depth rises, and the plot appears to show an upward sloping water surface. When it is recalled that the water surface shown represents depth, and not water-surface elevation, this problem vanishes.

The remaining entries relate to the scales to which the animation is shown. By default, scales are chosen which will in most cases adequately accommodate the entire simulation. Manipulation of the 5 ratios, RLLEFT, RLRGHT, RYBOT, RYTOP, and RFSZ enables zooming in to magnify some portion of the area of animation.

The default horizontal full scale is the length of run.

RLLEFT (default: 0.0) specifies the fractional length of run comprising the left boundary of the display, and RLRGHT (default: 1.0) specifies the fraction of length of run comprising the right-hand boundary of the display.

For example, to limit the display to the region between 80% of field length and 90% of field length, set RLLEFT=0.8 and RLRGHT=0.9.

Similarly, the default vertical full scale allows plotting points between the lowest bottom elevation and the field surface (or border berms).

RYBOT (default: 0.0) is the fraction of this full scale below which elevations are not shown, while RYTOP (default: 1.0) is the fraction of this full scale to which elevations are shown.

Depths of infiltration are always shown from 0.0 to some full scale.

RFSZ (default: 1.0) is the fraction by which the default full scale is multiplied.

RFSX, RFSY, RFSH, play similar roles and will not survive if user experiences demonstrates no need.

The Profile Table provides a list of irrigation times at which a record of the surface-water profile is desired (recall that all of the graphed information is stored in a text file which can be viewed from within SRFR or in any text editor; the file bears the same name as the data file, and an extension identical to the simulation number).

Hydrographs are prepared, by default, at the inflow and outflow sections. Discharge and depth can be recorded also at intermediate locations, to be entered in the Hydrograph Table in this window.

## **Results**

Performance Parameters are headed by a restatement of salient input conditions: length of run, border-strip width or furrow spacing, target depth of infiltration for the irrigation, inflow rate, and final cutoff time. The performance of the irrigation is then displayed in the following terms:

- **XCO** - advance at cutoff (if this is less than field end).
- **TL** - time for stream to advance to field end.
- **AE** - application efficiency, defined as volume infiltrated within the target depth, in ratio to the total volume of inflow, expressed as a percent.
- **PAEmn** - potential application efficiency of the min, is the application efficiency calculated on the basis of a new target depth, exactly equal to the minimum of the simulated distribution. Note that this is different from the standard definition of PAEmn, which calls for a cutoff time of just such magnitude that the resulting minimum depth just equals an independently given target depth. A simulation based on an arbitrary cutoff time cannot yield this value.

- **PAElq** - potential application efficiency of the low quarter, is the application efficiency calculated on the basis of a new target depth, exactly equal to the average of the simulated low quarter of the distribution. Note that this is different from the standard definition of PAElq, which calls for a cutoff time of just such magnitude that the resulting low quarter depth just equals an independently given target depth. A simulation based on an arbitrary cutoff time cannot yield this value.
- **DUmin**, the distribution uniformity of the minimum, is the ratio of the minimum depth of infiltration in the post-irrigation distribution to the average infiltration depth.
- **DUIq** - distribution uniformity of the low quarter, is the ratio of the average of the low quarter of infiltration depths to the average infiltration depth.
- **ADmin**, adequacy of the minimum, is the ratio of the minimum depth to the target depth of infiltration.
- **ADlq** - adequacy of the low quarter, is the ratio of the low-quarter average depth to the target depth of infiltration.
- **Dinf** - average depth of infiltration in the length of run after the irrigation is completed.
- **Dmin** - minimum depth in the post-irrigation infiltration distribution.
- **DIq** - average of the low quarter of post-irrigation infiltrated depths in the length of run.
- **RO %** - percentage of the inflow that runs off the end of the field as tailwater.
- **RO d** - volume of runoff, expressed as a depth over the field.
- **DP** deep percolation, represents the volume of infiltration, locally in excess of the target depth, expressed as a depth over the field.
- **Dapp** applied depth, is the volume of inflow expressed as a field depth.
- **Cost** - cost of irrigation water per unit area of field.
- **Ymax** - maximum depth of water in the border strip, basin, or furrow and indicates the degree of freeboard available. If an overflow condition has occurred during the simulation, the word OVERFLOW! appears. (Overflow is accounted for in furrow irrigation by means of the physical assumption that neighboring furrows on either side have identical flows; overflow is not accounted for in border or basin irrigation.)

The Performance Synopsis graph displays the longitudinal post-irrigation distribution of infiltrated water, as well as a series of numerical performance indicators: efficiency, uniformity, etc. The user can select performance based on the minimum depth in the distribution, or on the average low-quarter depth. And the distribution curve can be selected either as reflecting the actual, physical location of each infiltrated depth, or else ordered by magnitude, i.e., simply ranging from maximum to minimum, as a function of the percent of field area with that amount or more infiltrated.

The Hydraulic Summary is a combination graph, showing for each selected simulation: the inflow hydrograph, the advance and recession curves, the runoff hydrograph, and the longitudinal post-irrigation distribution of infiltrated water.

The Advance and Recession curves show these trajectories on a common set of axes.



If recession takes place well after the end of the advance phase, the time scale needed for plotting the two together makes the advance appear instantaneous. To view the behavior of advance with time, select the Advance Trajectory graph.

The longitudinal post-irrigation distribution of infiltrated depths can be viewed either as a function of distance down the field, or ordered in magnitude (see Performance Synopsis, above).

The infiltrated depths shown are field depths -- i.e., volumes per unit plan area of field, and so, for furrows, incorporate both the assumption made for the influence of wetted perimeter on infiltration and the furrow spacing.

The inflow, outflow (runoff), and any selected intermediate flow hydrographs are superimposed on a single time scale in this option.

Alternately, the inflow, outflow, and any selected intermediate depth hydrographs can be viewed superimposed on a single time scale in this option.

Water-surface-elevation profiles developed at selected times during the irrigation are viewed with this option. Alternately, depth profiles can be viewed.

### **Simulation Animation**

The screen is broken into two regions. The upper portion shows the irrigation stream, with its surface above the bottom of the flow channel a distance equal to the actual depth. The lower portion of the split screen displays the infiltration profile, drawn at a distance equal to volume infiltrated per unit field area. Thus the significance of the depth scales above and below the channel bottom is not exactly the same.

The water surface in isolated depressions sometimes appears humped, rather than level. This stems from the simplifying assumptions made to speed up the calculations of infiltration from such ponds. The effect on the infiltration distribution and recession times is negligible.

Shown on the animation frames (and influencing the vertical scale) are the top of the furrow (or top of border or basin berms). During periods of overflow (accounted for in furrow simulations with the physical assumption that neighboring furrows on either side have identical flows; not accounted for in border or basin simulations), a message appears on the screen, near the point of overflow.

The top of the furrow (field soil surface) or berms is assumed fixed with time, as the flow-channel bottom changes with assumed erosion or deposition.

Also shown is the target depth of infiltration. The default vertical scale is influenced by this amount, and by the total expected depth of infiltration.



## 4 Terminology

### Water Flow

- Q** - Inflow Rate
- R** - Cutoff Ratio - Ratio of advance at cutoff to field length.
- Tco** - Cutoff Time
- TL** - Advance time to end of the field.

### Infiltration

Kostiakov Formula:  $Z_n = k * T_n^a$

- Zn** - Infiltration depth at time  $T_n$ .
- k** - Coefficient constant. Represents the relative ease at which water infiltrates into the soil. The larger **k**, the easier water infiltrates into the soil. Sandy soils will have larger **k** values than clay soils.
- Tn** - Time.
- a** -  $T_n$  exponent. Represents the change in infiltration rate as the soil saturates with water. The value of **a** is between 0.0 and 1.0 (usually between 0.3 and 0.8). The larger **a**, the slower the infiltration rate changes as the soil absorbs water. Sandy soils will have larger **a** values than clay soils.

Modified Kostiakov Formula:  $Z_n = k * T_n^a + b * T_n + c$

See Kostiakov Formula above for  $Z_n$ ,  $k$ ,  $T_n$  &  $a$  terminology.

- b** - Constant infiltration rate.
- c** - Immediate infiltration depth due to newly tilled or cracked soil. This represents water that quickly flows into air spaces in the soil.

### Infiltrated Depth

- d(x)** - Function describing the infiltrated depth along the length of a field.
- Dapp** - Average depth of applied water, or, applied volume expressed as an equivalent average depth.

$$D_{app} = D_{inf} + D_{ro} \quad \text{and sometimes approximately}$$

$$D_{app} = D_{req} + D_{dp} + D_{ro}$$

**Ddp** - Average depth deep percolation, or, deep percolation volume expressed as an equivalent average depth.

**Dinf** - Average depth of infiltrated water, or, infiltrated volume expressed as an equivalent average depth.

$$Dinf = Dreq + Ddp \text{ (approximately)}$$

**DIq** - Low quarter average infiltrated depth = average depth for quarter of field receiving the least infiltrated depth (not necessarily contiguous).

A function of  $d(x)$

**Dmin** - Minimum infiltrated depth.

Minimum of  $d(x)$

**Dreq** - Required or target application depth.

**Dro** - Average depth of runoff, or, runoff volume expressed as an equivalent average depth.

**Dz** - Infiltrated depth contributing to the irrigation target

$$Dz = Dinf - Ddp$$

### **Performance Measures**

**RO%** - Runoff fraction

$$RO\% = Dro / Dapp$$

**DP%** - Deep Percolation fraction

$$DP\% = Ddp / Dapp$$

**ADlq** - Low-Quarter Adequacy

$$ADlq = DIq / Dreq$$

**ADmin** - Minimum Adequacy

$$ADmin = Dmin / Dreq$$

**DUlq** - Low-Quarter Distribution Uniformity

$$DUlq = DIq / Dinf$$

**DUmin** - Minimum Distribution Uniformity

$$DUmin = Dmin / Dinf$$

**AE** - Application Efficiency

$$AE = Dz / Dapp$$

**PAElq** - Low-Quarter Potential Application Efficiency

$$PAElq = DUlq * (1 - RO\%)$$

**PAEmin** - Minimum Potential Application Efficiency

$$AE = Dz / Dapp$$

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